ENGINEERING NEWS

A JOURNAL OF CIVIL, MECHANICAL, MINING AND ELECTRICAL ENGINEERING

Vol. LI. No. 10. New York, March 10, 1904.

TABLE OF CONTENTS

	Page
LEADING ARTICLES:	
The Collapse of the Darlington Apartment House in New York City (illustrated)	217
The Lubrication of Locomotive Valves and Cylinders. D. R. MacBain	219
A Compact Design of Automatic Electrically Driven Pump (illustrated). E. Guarini	220
High-Speed Trains and Train Service	220
Fireproof Buildings in the Rochester Fire (illustrated)	220
Tests of the Adhesion and Initial Stress of Steel in Concrete (illustrated). Sam. W. Emerson	222
Russell Wheeler Davenport (with portrait)	223
A Decade in American Blast-Furnace Practice. F. Louis Grammer	220
Machine-Mixed Concrete as Applied to Street Work (illustrated). D. G. Fisher, M. Am. Soc. C. E.	231
A New Jointing Material—Sulphur and Sand—for Sewer Pipes. Alexander Potter, C. E.	231
Notes on Rail-Steel. Robert W. Hunt	232
The Construction and Use of Coucrete-Steel Piles in Foundation Work (illustrated). A. W. Buel and Chas. S. Hill	233
Grain Pressures in Deep Bins (illustrated). J. A. Jamieson, M. Can. Soc. C. E.	236
Plant and Buildings of the Hecla Portland Cement & Coal Co. (illustrated)	243
Notes on the Physics of Cast Iron. Richard Moldenke, M. Am. Inst. Min. E.	245
Notes on Gold Dredging in New Zealand. Gilbert Winslow, B. A.; Assoc. M. Inst. C. E.	247
Rate of Evaporation at Yuma, Ariz.	248
Direct-Metal and Cupola-Metal Iron Castings. Thos. D. West, M. Am. Inst. Min. E.	248
ENGINEERING NEWS OF THE WEEK	223
EDITORIAL COMMENT.—Fresh Water or Salt Water for an Auxiliary Fire Protection System in New York City——Some Notable Experiments on Pressures in Grain Elevator Bins——A Convenient Formula for Grain Bin Pressures——The Evolution of Gold Dredging——Driving Concrete Steel Piles with Hammers——Sanitary Improvement the First Step in Panama Canal Construction——Our Record-Breaking Exports of Manufactured Goods	224
EDITORIAL.—If Not an American Engineering Building, Why Not an American Engineering Library?	225
LETTERS TO THE EDITOR.—How to Prevent the Bends: "The Captain"—Proposed Rearrangement of the Brooklyn Bridge Terminals: Julius Meyer, G. Lindenthal——Material Required to Make Different Classes of Concrete for Connecticut Ave. Bridge, Washington, D. C.: W. J. Douglas——A British View of American Schools: F. B. Sanborn——Courses of Instruction in Railway Engineering: George F. Morse——The Consideration of Adhesion Between Concrete and Metal in Calculating Concrete Steel Beams: Edward Godfrey——A Proposed Method of Computing the Stresses in Concrete-Steel Beams (illustrated): Wm. T. Walker——A Proposed Method for Reinforcing Concrete Beams Against Shear (illustrated): H. F. Wilson, Jr.——A Criticism of Methods of Allowing for Shrinkage in Earthwork Computations: John A. Fulton——Precautions Against Typhoid Fever in Contractors' Camps: C. R. Coutlee——Problems in Laying Out Curves: "Subscriber"——Geo. H. Tinker, S. N. Daugherty, Arnold Emch	226-228

THE COLLAPSE OF THE DARLINGTON APARTMENT HOUSE IN NEW YORK CITY.

The fall of a partially completed metal frame building in New York city on March 2 caused the death of at least 25 persons, most of them workmen engaged on the construction of the building. A 13-story apartment house, of which the metal framework and the concrete floors had been completed almost to the roof, collapsed at about 1.30 p. m. of that day, without warning. The destruction of the building was complete, and a week's work by a large wrecking force has not sufficed to wholly remove the confused heap of wreckage.

The failure is startling, not because of the deplorable loss of life, but because scores and hundreds of buildings are standing or are being built in New York city and elsewhere, of the same character and under the same conditions as the collapsed Darlington. These buildings are the homes of thousands of families. The Darlington building had been designed and was being built under the Building Code of the City of New York, a code which is far in advance of most municipal building regulations and which is cited as a model. The principle of structural design which this code embodies closely approximate to recognized standard practice in the field of building according to modern methods. It is not surprising, therefore, that the failure has awakened among architects and structural engineers a feeling near to consternation.

Because of the complete ruin of all of the building that had been erected, and because nearly all persons who were in the building at the time of the collapse are dead, including those in charge of the work, it has not been possible up to the present to determine, with even approximate probability, the cause or causes of the collapse, or even all the conditions of the work which may have a bearing on the accident. The following brief account of the matter, therefore, can only depict the general circumstances as known at present.

The building in question, called the Darlington Apartments, stood on the north side of 46th St., 205 ft. east of 6th Ave., in the Borough of Manhattan, New York city. The lot on which it was being built, Nos. 59 and 61 West 46th St., was 55 ft. wide east to west, and 100 ft. 5 ins. deep, running back half the depth of the block to 47th St. To either side of the lot were four-story brick dwellings, while to the rear was an eleven-story apartment house known as the Patterson, fronting on 47th St. The Darlington was planned to cover the entire lot with the exception of a narrow strip at the rear, about ten feet wide, and two light-courts, one in the middle of each side. It was to have 12 main stories above ground, a cellar and a "penthouse" over the larger half of the roof, making a thirteenth story. The total height from sidewalk level to top of penthouse roof was about 148 ft. The normal story-height in this building was 10 ft. 10 ins., between floor surfaces.

The building was designed by Neville & Bagge, architects, of 217 West 125th St., for the Allison Realty Co., owners. The architects have stated publicly that they had nothing to do with the construction or supervision of construction, and were not even responsible for the finally-adopted iron plans. They had been engaged solely to draw up a set of plans and secure the necessary permits for the construction of the building. The contract for furnishing and erecting the metal framework was let to the firm of Pole & Schwandtner, Civil Engineers and Contractors, of 76 William St., New York city. This firm made (and filed) most of the final plans for the iron framework, and was engaged in the erection of this framework at the time of the failure.

Structurally speaking, the Darlington building was a brick curtain-wall building with steel floor-framing and cast-iron columns.* The wall columns were enclosed in the brick walls. In general, the walls were self-supporting, and not carried by beams supported on the columns. There were no interior walls, the fireproof partitions being carried by the floor-system. The floors, being put in by the Roebling Construction Co., of New York, were of the Roebling flat reinforced-concrete type (System B, style 4, of that company's standard constructions). This is substantially a flat floor-plate of cinder concrete, with flat bars set on edge spanning across between the lower flanges of the floor-beams and constituting the reinforcement of the concrete plate. The lower 4 inches of the concrete is made richer than the remainder, which latter acts mainly as a filler. The thickness of the floors in this building is 13 ins. from finished ceiling to finished floor surface.

VIEW OF DARLINGTON RUINS FROM LEFT CORNER OF FRONT.
(The cut-stone work at extreme left is part of the front-wall masonry.) Photograph by H. N. Tiemann, New York.

The accompanying drawing, Fig. 1, shows a floor-plan of the framing of the wrecked building, drawn to scale. The front and rear halves are practically alike in dimensions and framing, so that this is shown for the front half only. The

*Except that the uprights supporting the penthouse roof were steel T-bars, 4 x 4 ins.

strip at the rear and the side light-courts I. and II. are roofed over at the second floor level, and on the ground floor form part of the first story space. The framing shown in Fig. 1 is that for the 3d to 8th floors, as shown by the plans on file in the Bureau of Buildings of the Borough of Manhattan. The 9th to 12th floors and the penthouse floor are similar in arrangement to that shown, but their framing is somewhat lighter. The penthouse covers all of the building except the front wing; its roof differs somewhat in arrangement from the tiers below and is lighter in framing. The first and second floors, due to the addition of framing for the light-courts, are different in arrangement from the tiers above, and the first floor is heavier. In general, the floors are calculated for 120 lbs. per sq. ft., total load, of which 60 lbs. is dead load and 60 lbs. live load.

Turning to the columns, we find that square cast-iron columns were used throughout the building (except for the penthouse uprights as already noted). Their location and their relation to the beam-work are indicated by the framing-plan, Fig. 1. It will be seen from this that a considerable number carry beams on one side only. The eccentricity of this one-sided loading is largest in the case of the front wall columns, where it reaches about 12 ins. To exhibit the sizes of columns used we have selected as typical the columns marked A and B in Fig. 1. The column schedule gives the sizes of these columns in the

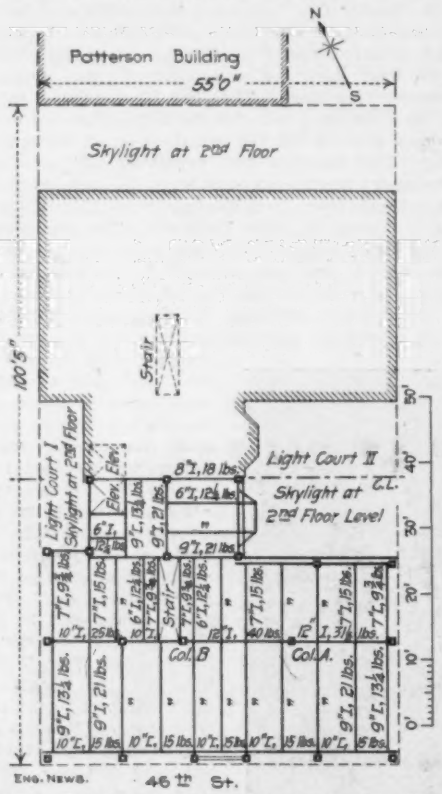


Fig. 1. Typical Floor-Plan of Darlington Apartment House.

successive stories as below. For column A we have also noted the calculated column loads, in tons of 2,000 lbs.

Story.	Column A. Load, tons.	Column A. Size	Column B. Size
12th	14.5	6" × 6" × ¾"	6" × 6" × ¾"
11th	29	6" × 6" × ¾"	6" × 6" × ¾"
10th	43.5	6" × 6" × ¾"	6" × 6" × ¾"
9th	58	6" × 6" × ¾"	6" × 6" × ¾"
8th	72.5	6" × 6" × ¾"	6" × 6" × ¾"
7th	87	6" × 6" × 1"	6" × 6" × ¾"
6th	101.5	7" × 7" × 1"	7" × 7" × ¾"
5th	116	7" × 7" × 1"	7" × 7" × 1"
4th	130.5	8" × 8" × 1"	8" × 8" × 1"
3d	145	8" × 8" × 1¼"	8" × 8" × 1"
2d	159.5	9" × 9" × 1"	9" × 9" × 1"
1st	174	10" × 10" × 1¼"	9" × 9" × 1"
Cellar	188.5	10" × 10" × 1¼"	9" × 9" × 1"
Cast-iron bases		2' 8" × 2' 8" × 1' 4"	2' × 2' × 1' 4"
Granite blocks		4' 4" × 4' 4" × 1' 6"	3' 6" × 3' 6" × 1' 6"

The footings for the above are marked "granite blocks," but it is not certain that these were used in the building as actually constructed; it is probable that concrete footings were used, wholly or in part. The nature of the foundation upon which the footings rested is referred to farther on.

The character of the details of the ironwork in this building appears to have been fairly regular. The framing connections of the beams were generally of standard size as given in the steel-manufacturers' handbooks (the beams and channels were of Carnegie and Phoenix make). However, the connections were bolted throughout, as well in attaching the connection angles to the ends of the floor-beams as in fastening them to the webs of the girders. The column details were generally in accordance with usual practice in cast-column building work. The end connection flanges were 1½ ins. thick, projecting 3 ins., and fastened with two bolts on each side (flanges being provided on two opposite sides only). The brackets and lugs for attaching the beams were of regular design and apparently adequate. The bracket seats for the beams were beveled away from the column to prevent concentrating the weight at the outer corner. The eccentricity of the connections of the wall-channels to the front wall columns has already been noted. The brackets for these connections were not beveled, as the channel came upon them from the side, and they had no lugs for web-connecting the channels.

On March 2 the iron framework of the Darlington had been erected up to the tenth floor level. The concrete floors had been placed to within two or three floors of the ironwork, and work on them was rapidly progressing. The side and rear walls had been built to a height of about three to six stories, the side walls being farthest along. The front wall was only begun. A large boom-derrick was on the upper tier of beams, for hoisting and erecting the ironwork. This derrick was located on the front wing of the building, so as to hoist material from the street. On the tier last erected there was stored a large part of the ironwork required for the erection of the tier or tiers above. The exact amount of this material is not yet known, nor is it known whether the last tier put in place had been fully bolted up and whether any erection rods or other braces were put in to stiffen the framework during erection.

The collapse occurred at about 1.30 p. m. of March 2. The manner of failure is variously described by the few eye-witnesses who were able to give any clear account. As precise a description as we have heard is given by an invalid lady whose apartment is quite near and fronting toward the wrecked building. She had frequently looked on from her window at the rapid erection of the framework of the Darlington. At about the time of the collapse she was looking directly at the building, when the structure began to sway alarmingly. She called in fright to a companion who was in another room, and the latter reached the window before the collapse occurred. The story of another observer is similar to the preceding, with the addition that the building swayed, and threatened to fall forward into the street; then stopped and seemed to be drawn inward toward the center, and fell together. The direct vertical collapse which all witnesses testify to is strikingly corroborated by the fact that the wreckage was all piled up within the area on which the building stood. A small amount of it spread out over the sidewalk in front, and another small part spread to the rear; but substantially the ruins are confined to the building lot itself. The

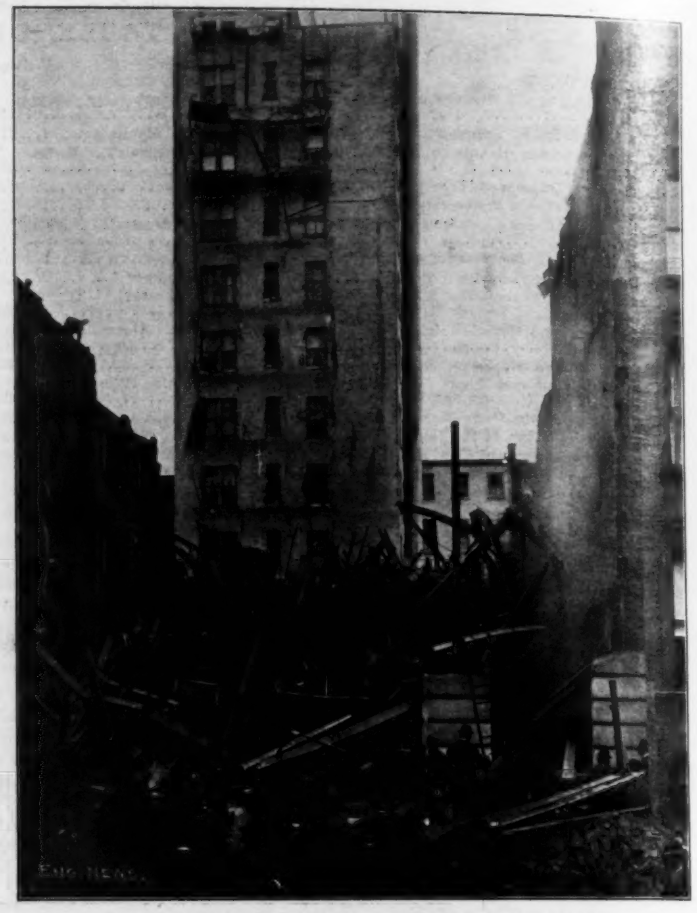


FIG. 2. FRONT VIEW OF RUINS OF DARLINGTON APARTMENT HOUSE, SHOWING PATTERSON IN REAR.
(Photograph by H. N. Tiemann, New York.)

appearance of the wreck is well illustrated in the view shown on the preceding page. A more complete idea of the small spread of the wreckage may be obtained from the views, Figs. 2 to 4, herewith. Fig. 4 exhibits the small amount of material that fell into the open yard behind the eastern portion of the lot. West of this the Patterson building, seen in Fig. 2, abuts upon the lot. This building is of about the same height as the completed portion of the Darlington, and its rear face was scraped nearly all the way from the top by the falling structure. The injuries done to the brickwork of this wall are shown by Fig. 2, which also indicates how the fire-escapes were torn off. The lower story of this building had an extension similar to that in the rear of the Darlington; this extension was crushed in by the falling mass and a woman seated at dinner was killed. This was the only victim who was not in the collapsed building.

In connection with the vertical collapse shown by the small spread of the wreckage it is of interest to record the remarkable escape of a workman. Several men were at work on the tenth floor of the Darlington at the time of the collapse; all of them were killed except one, who was later picked out of the top of the ruins little injured beyond bruises. His escape must be charged to a rather gradual and broken fall of the portion of floor upon which he stood.

The effect of the collapse on the structure of the building is shown by the views herewith presented to be utter destruction, as we have already described it. The floor-framing was thoroughly torn apart. Only in few cases was anything approaching a full panel of framing left hanging together. Many of the floor-beams, how-

even remained attached to the girders at one end. The beams and girders were bent, twisted and battered by the fall, in a way that shows a good soft steel. Only here and there is a short crack to be seen in the end of the web. The connection angles also seem to have stood remarkably well. Where beam and girder were torn

FIG. 3. VIEW OF DARLINGTON RUINS FROM LEFT-FRONT.
(Photograph by H. N. Tiemann, New York.)

apart, the angles usually remained attached to the end of the beam. In a number of cases the connection angles were torn or broken, but generally the bolts sheared or tore off.

The columns were practically all of them broken. Nearly every column broke in the flanges which connected successive lengths. Some had both flanges of one end broken off, while others have one flange remaining, with the broken-off flange of the contiguous length still held to it by the bolts. Failures of the beam-brackets on the columns were much more rare. Where these were broken, in some cases the lug (for the web-connection) was broken, in fewer cases the bracket seats. In a few cases these brackets were broken off completely at the root, shelf and knee. A number of columns, particularly the smaller ones of the upper stories, were broken across the body, usually square across near one end.

The floor concrete was dashed into fragments by the fall, filling up the heap of ruins with a mass resembling wet ashes. Few lumps large enough to handle were left.

The columns in the side and rear walls of the building remained standing up to the second or third story level. The columns around light-court H. and the framing of this court remained in place up to the second floor, and the columns of light-court I., up to the third floor level. In the front wing of the building the first floor framing was broken away, but the cellar columns were not overthrown. In the rear wing the central portion appears to be gone, but the first floor work appears to be left in the two extreme corners. At the time of writing nearly half of the debris still remains to be removed, so that a full statement of the conditions at the bottom cannot be made.

In considering the collapse one fact becomes important: the design and construction of the Darlington had almost from the first given rise to a series of complaints and objections on the part of the inspectors of the city Bureau of Buildings. The original plans for the structure were filed May 7, 1903, but the final iron plans were filed only on Dec. 24, 1903, a number of changes having been made before this time. Several months before this, in August, the city inspector had reported that in the front of the Darlington lot the foundation was bed-rock, but that it sloped off to clay in the rear. He recommended that the footings be enlarged where they rested on the clay. It is not known whether they were actually enlarged in compliance with this recommendation. During January and February, 1904, while the erection of the framework was going on, there were several complaints by the inspectors, relating to the manner in which the construction was being carried on. The last of these complaints was made only the day before the collapse, and was filed on the morning of March 2. It reports

a violation of Section 41 of the Building Code, as follows: In that of constructing the side walls more than two stories in advance of front wall, and also the floor-beams were not all properly bolted and tied.

It is not quite clear what the last clause refers to, but it is worth noting that a previous objection to the plans had been that tie-rods should be provided between all the floor-beams. It is possible that the upper tier or tiers last erected had not been fully bolted or provided with tie rods. The walls, it is known, were several stories behind the framework, so that the latter had no bracing other than what may have been put in place in the way of sway-rods or diagonal shores. The condition of this part of the work will not be known until the inquest is held.

The matter of the foundation is given additional weight by the following facts: It is claimed by old residents of the city who are familiar with early conditions at that location and with maps of the site that a small stream formerly had its origin at about the location of the Darlington building. A number of small springs fed this creek. Rock is generally close to the surface in the neighborhood of the building, and much blasting was necessary in the front part of the lot to get down to the foundation level (an old church stood on the site before the erection of the Darlington was begun). Pockets and dips in the surface rock of New York city are not rare, and these are usually filled with a soft, unreliable material, either original or filled. The report of the building inspector that the rear of the foundation of the Darlington sloped off to "clay" is recalled. The owner of the Patterson building, directly adjoining at the rear of the lot, gives some further testimony. He is quoted as saying that when the foundations for his building (see Fig. 1) were being constructed

the men came upon two beds of quicksand, which gave them trouble and which necessitated an additional outlay of $10,000 before they could be overcome. The beds of quicksand were under the east wall of the Patterson building, and another under the rear wall. We had to go down thirty feet before we struck bedrock.

The Coroner and the District-Attorney have retained engineers as experts to aid in determining the conditions and causes of the collapse. The inquest on the killed will begin probably at the close of the present week. We reserve comment upon the accident until our next issue.

MASSACHUSETTS VS. PENNSYLVANIA in relation to typhoid fever death rate. The "Journal of the Massachusetts Association of Boards of Health" in its February number comments on the typhoid fever epidemic at Butler, Pa., as reported upon for this journal by George A. Soper, Ph. D., in our issue of Dec. 24, 1903. After giving the chief facts in the case the "Journal" says that: "The epidemic is a stern and severe arraignment of the wealthy state of Pennsylvania, her legislature, her people and her boards of health." As shown in the report referred to, there are no vital statistics in Pennsylvania worthy of the name; and no adequate sanitary supervision of the water supplies of the state. To show what may be accomplished by proper supervision and a moderate expenditure of money—backed by intelligent public sentiment, the "Journal" prints the following table, giving the number of deaths by typhoid fever per 100,000 population, in some of the principal Massachusetts and Pennsylvania cities. This table conveys its own lesson:

Average Typhoid Fever Death Rate.
(1898—1899—1900.)

Pennsylvania.		Massachusetts.	
City.	Death rate	City.	Death rate.
Pittsburg	108	Boston	30
Allegheny	86	New Bedford	30
Johnstown	83	Springfield	26
York	83	Lawrence	25
Chester	64	Taunton	25
Lancaster	59	Brockton	24
Philadelphia	54	Chelsea	24
McKeesport	53	Salem	23
Reading	50	Fitchburg	21
Allentown	49	Lawell	21
Harrisburg	41	Lynn	20
Altoona	33	Newton	20
Wilkesbarre	29	Cambridge	18
Erie	28	Worcester	18
Scranton	23	Fall River	15

THE LUBRICATION OF LOCOMOTIVE VALVES AND CYLINDERS.*

By D. R. MacBain.†

Some 15 or 20 years ago when the maximum steam pressure in locomotives was about 140 lbs., there was little difficulty with valve and cylinder lubrication. The low steam pressure and perhaps a little better class of cast

Fig. 4. View Looking North Over Rear Corner of East Wall of the Darlington Apartment House, Showing Wreckage in Court East of Patterson.
(Photograph by H. N. Tiemann, New York.)

iron used in cylinders and valves, made the matter of proper lubrication a simple one.

The writer has watched the rise in steam pressure from 140 to 220 lbs., and has noted the gradual increase of trouble with lubrications.

The slide valve, though balanced to the highest possible degree that would insure its remaining on the valve seat when working at high speed and short cut-off, is, at

*Abstract of a paper read at the February meeting of the Western Railway Club, at Chicago, Feb. 16.
†Master-Mechanic, Michigan Central Ry., Jackson, Mich.

best, with the present high steam pressure, a difficult problem when it comes to the matter of lubrication. This is particularly true on runs where the throttle is not closed for a distance of 25 miles and upwards, and where for reasons of fuel economy and in the attempt to get the best out of the engine, the engineman uses a wide throttle.

"The writer is perfectly satisfied that on long runs, such as described above, either one or the other of two things must be done; 1, ease the throttle off frequently so that steam chest pressure will fall much below that of the boiler, or, 2, run with a longer cut-off and a smaller throttle opening that will keep steam chest pressure down enough so the lubricator will feed.

The long cut-off and short throttle has become the most acceptable method among enginemen, and it is safe to say that this fact is responsible in a large degree for the increase in fuel consumption that has become nearly universal.

If engine runners would see that the valves and cylinders of their locomotives are properly oiled before starting out, and that no more water than is absolutely unavoidable is worked over valve seats and cylinders, no difficulty would be experienced in keeping the rubbing surfaces fairly well lubricated even with a wide open throttle, provided the throttle is eased off (for a moment), say every five to eight miles.

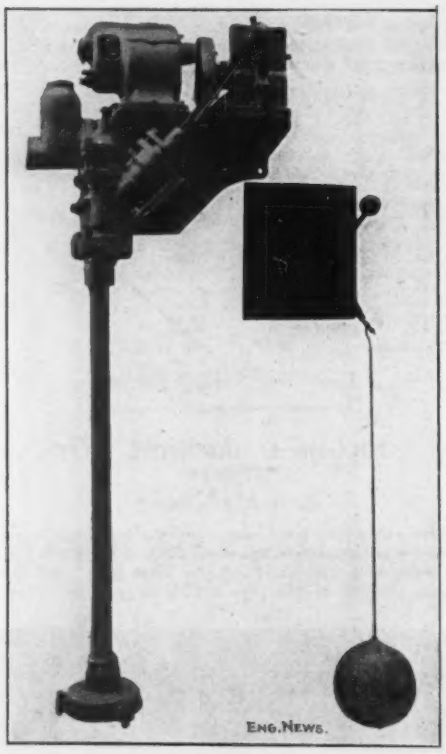


Fig. 1. Automatic Motor-Driven Drainage Pump, With Float Controller.

On freight trains the cut-off is seldom so short that the pulsations or variations of pressure in steam chest will not permit of the oil passing freely from the lubricator forward, and what is recommended in this case is absence of saturated steam and enough oil.

The piston valve has taken away from the enginemen much of the annoyance experienced with the slide valve, the two particular items of annoyance being the noise caused by the reverse lever trying to tear away from its notch in the quadrant and the jerking, when it was desired to change the cut-off. The piston valve, however, does get very dry, but it will not rattle, nor jerk the arms out of the engineman when the cut-off is being changed.

The fact that the engineman is secure from annoyance and physical effort is something which is costing railway companies a lot of money, not alone in the matter of unnecessary wear and tear, but also in unnecessary fuel consumption. As the piston valve has simply transferred the worry about lubrication from the engineman to the stockholder, it would seem that in order that the latter may have justice, some rule should be laid down to govern the matter of quantity of oil to be used and enginemen educated to understand and respect the same; to specify a particular number of drops per minute means nothing, unless work performed per minute is taken into account. Water glasses on locomotives should not be more than three gages long. Proper facilities should be provided for getting rid of condensation easily and quickly when starting up, and rod packing should be kept in good condition in order that the oil may not be wasted.

TABLE No. I.—Fast Trains in the United States and in Europe.

Stations.	Railroad.	No. of stations stops.	Miles.	Speed, miles per hr. Journey.	Speed, miles per hr. Running.
Atlantic City to Camden..	P. & R.	0	55.50	67.96	67.96
Atlantic City to Camden..	Penn...	0	58.00	66.92	66.92
Camden to Atlantic City..	P. & R.	0	55.50	66.60	66.60
Camden to Atlantic City..	Penn...	0	58.00	64.44	64.44
Paris to Calais.....	Nor....	1	185.14	58.46	59.72
Paris to Calais	Nor....	1	185.14	55.08	56.10
New York to Buffalo*....	N.Y.C..	4	439.52	53.27	54.40
London to Edinburgh....	G. N...	3	395.00	50.96	52.78
Berlin to Hamburg		1	177.69	51.50	52.51
London to Edinburgh...	L.&N.W.	3	400.00	50.00	51.61
London to Plymouth	G. W...	2	246.00	47.61	50.89
New York to Chicago....	N. Y. C. & L.S.	11	962.49	48.12	49.31
London to Plymouth ..	L. & S.W.	3	230.75	45.24	47.25
Calais to Vintimille.....		20	892.86	42.01	46.30
Ostend to St. Petersburg.....		34	1599.35	35.30	38.60
Paris to Madrid		46	903.99	33.70	38.49
Ostend to Vienna		23	822.16	34.76	37.85
Berlin to Milan		13	782.65	34.52	36.43
Chicago to San Francisco†.....		39	2569.00	32.79	33.75
Chicago to San Francisco‡.....		44	2314.90	32.32	33.58
Paris to Constantinople.....		52	1931.99	31.36	33.43

*Empire State Express.
†(Port Richmond), A., T. & S. F. Ry.
‡(Oakland), C. & N. W. and So. Pac. Rys.

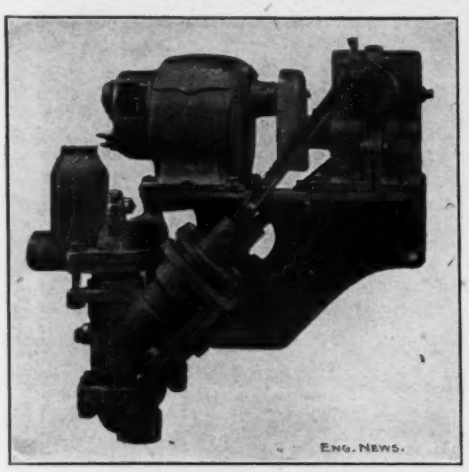


Fig. 2. View of Bracket Frame, with Motor, Gears and Pump in Place.

A COMPACT DESIGN OF AUTOMATIC ELECTRICALLY DRIVEN PUMP.

By E. Guarini.*

For the purpose of dealing with the water that may accumulate in conduit manholes, cellars, pits and similar places, the British Thomson-Houston Co. has introduced a small combined motor and pump of remarkably compact design. It is shown in the accompanying photographic views.

The pump is a duplex single-acting plunger pump, having a capacity of 7½ gallons per minute, and suitable for pressures up to 55 ft. head. The pump barrels, which are inclined upward from the valve chambers, are of cast iron, while the plungers, valves and seats and connecting rods are of special hard and tough gun metal. The sole plate consists of a bracketed casting arranged to bolt on a wall; it has machined seats to receive the pump barrels, motor and gear case.

The pump is driven by a ¼-HP. direct-current bipolar motor through double-reduction gearing: a spur pinion and gear, and a worm-wheel with gear. Both pairs of gears are enclosed in gear cases. The worm-wheel, which is of bronze, runs in oil, and has a ball thrust-bearing.

The motor is controlled automatically by the rise and fall of the water in the pit raising and lowering a copper ball float connected by a rod to a fall-over switch, giving quick opening and closing of the contacts. The float and switch are shown at the right in Fig. 1.

The pump is fitted with grease lubricators, and the motor with the usual oil-ring lubrication. The entire apparatus requires very little attention. The motor is designed to run on ordinary lighting circuit pressure, and can therefore be used almost anywhere.

*70 Boulevard Charlemagne, Brussels, Belgium.

TABLE No. II.—Comparison of Fast Trains in the United States and in Germany.

No. of trains.	American.	German.
Total No. averaged	306	322
Over 40 miles per hour (A).....	90	18
Over 40 " " " (B).....	122	45
40 to 45 " " " (B).....	74	38
45 to 50 " " " (B).....	36	4
Over 50 " " " (B).....	12	3

A: Journey speed. B: Running speed.

HIGH-SPEED TRAINS AND TRAIN SERVICE.

A pamphlet has recently been issued by Mr. George G. Tunell, of Chicago, which contains a reprint from the Journal of Political Economy on the subject of American and European high-speed trains, and which puts on record an interesting comparison as to the noted fast trains of the world. A tabular statement of these trains, somewhat condensed, is given in Table No. I.

The term "running speed," in the last column, denotes the speed between stations, or the average speed obtained by deducting station stops. The term "journey speed," in the next column, denotes the average speed including stoppages, from the start to the final stop. In classifying trains by speed, the latter, or "journey speed," should be considered as of greater importance, since the time consumed in the journey is the important feature. Rapid running between stations, accompanied by long delays at stations, does not shorten the time of the journey as a whole, but adds to the danger of the journey.

Mr. Tunell also gives an interesting comparison of the number and speed of trains between important cities in this country and in Germany, which is summarized in Table No. II.

In the table No. III. is given an interesting summary of the train service between important cities in this country.

FIREPROOF BUILDINGS IN THE ROCHESTER FIRE.

A fire of unusual magnitude swept the shopping district of Rochester, N. Y., on Feb. 25 and 26, and destroyed about $3,000,000 in property. Coming so soon after the Baltimore conflagration this most recent fire disaster has attracted less attention than its character and dimensions warrant. There was only one fireproof building in the Rochester fire and this was not of the most recent construction, but the hazards to which this building was subjected make its combustion of exceptional interest to architects and engineers. The 13-story Granite Building at Rochester was the victim of exposure hazards of the most inexcusable character.

The accompanying map, Fig. 1, of the burned district at Rochester shows at a glance the conditions which existed. At the corner of St. Paul and Main Sts. was the 13-story Granite Building. This structure had self-supporting walls enclosing a skeleton frame of round cast-iron columns and rolled steel I-beam girders and floor beams. The floor arches were of end construction terra-cotta; the partitions were of 4-in. tile, and the columns were covered with a casing of solid terra-cotta segments. The skewback tiles of the floor arches lapped slightly under the beam flanges and formed a groove into which was slipped the dove-tailed flange tile. The partitions had wooden strips at the top. The room floors were of wood and all windows, doors, door casings, partition windows and sash, and finish generally were of wood. The halls were floored with marble and had marble wainscoting. The first story stairs had marble treads and the others had slate treads. The wings of the building each had an elevator shaft from basement to the top; these shafts terminated in pent houses on the roof. There were also two stairway shafts, also terminating in roof pent houses. In general the building was a fair example of steel

TABLE No. III.—Train Service Between American Cities.

Stations.	No. of trains averaged.	Average miles.	Ave. miles per hr. Journey speed.	Ave. miles per hr. Running speed.
New York (J.C.) to Phila.	55	90.30	41.38	43.52
Philadelphia to Baltimore..	34	95.75	39.86	41.90
Philadelphia to Buffalo ...	9	422.30	36.22	39.87
New York to Buffalo	30	432.68	37.30	39.46
New York to Boston	21	232.53	35.26	39.06
Buffalo to St. Louis	3	741.00	36.41	38.78
Baltimore to Buffalo	2	396.00	36.20	38.54
Boston to Buffalo	8	491.80	36.04	38.01
Cleveland to St. Louis....	5	558.00	35.53	37.83
Buffalo to Cleveland.....	16	197.75	33.22	37.51
Philadelphia to Pittsburg..	10	353.70	34.10	37.12
Buffalo to Chicago	13	546.70	33.78	36.84
Cincinnati to St. Louis....	6	356.33	32.75	36.45
Pittsburg to St. Louis	7	660.00	32.29	36.24
Cleveland to Chicago	14	359.59	33.31	35.62
Baltimore to Pittsburg....	7	336.22	33.42	35.54
Cincinnati to Chicago.....	11	306.11	32.98	35.43
Cleveland to Cincinnati ...	8	287.30	30.11	35.26
Pittsburg to Chicago	8	482.90	32.47	34.77
Chicago to St. Louis.....	10	286.51	31.16	34.06
Pittsburg to Cleveland ...	12	146.00	28.50	34.31
Baltimore to Cincinnati ...	3	392.00	32.24	34.27
Pittsburg to Cincinnati...	7	328.00	31.10	33.68
Buffalo to Pittsburg.....	7	252.00	29.34	32.55

skeleton fireproof construction as it was practiced ten years ago; structurally the building was a good hazard from the insurance man's point of view.

The street floor and basement of the Granite Building was a dry-goods shop owned by the Sibley, Lindsay & Curr Co. The same company also occupied the seven-story building to the north and

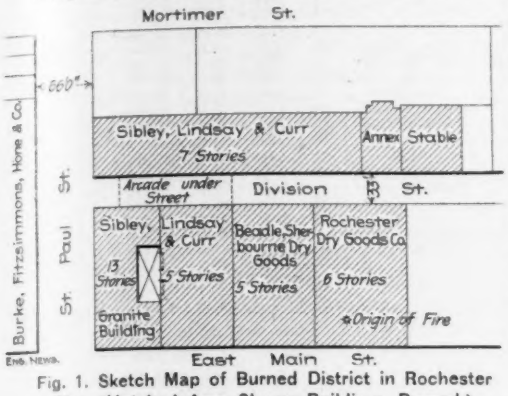


Fig. 1. Sketch Map of Burned District in Rochester Fire. (Hatched Area Shows Buildings Burned.)

on the opposite side of Division St., and the five-story Marble Building to the east and adjacent on Main St. Connecting the seven-story wholesale store with the Granite Building there was an "arcade" under Division St., as indicated on the sketch map. In addition there was a bridge over Division St. with connections to the second, third, fourth and fifth floors of the Granite Building, from the corresponding floors of the wholesale building. These four openings to the Granite Building are clearly shown by the view, Fig. 2. The total area of these buildings, plus the area of the arcade opening, was about 1,500 sq. ft. On the east, the street floor of the Granite Building was connected with the same floor of the Marble Building by an opening embracing the total width

Fig. 3. View of East Side of Granite Building Showing Light Shaft and Ruins of Abutting Marble Building.

of the light shaft and the north wing. The area of this opening is shown clearly by Figs. 3 and 4. Finally, the party wall between the north wing of the Granite Building and the abutting Marble Building had connecting openings on the second, third, fourth and fifth floors. The area of the openings into the Marble Building was probably not less than 2,000 sq. ft. The Granite Building was thus connected by wide openings with the buildings next to it on both the north and east. None of the connecting openings were closed so far as is known except those giving the bridge floors access to the Granite Building and these had rolling iron shutters.

Above the street floor the Granite Building was occupied by offices, except the north wing for five stories which was used as a part of the store of Sibley, Lindsay & Curr, it therefore had numerous windows on all four sides and particularly in all three sides of the light shaft. None of these windows was protected by shutters and all had wooden casings and sash and were glazed with plain glass. The adjacent Marble Building on Main St. had brick walls and wooden joist floors; it was in no sense a fireproof structure. It was built in 1856. The wholesale building across Division St. had heavy brick exterior walls and brick arch floors carried by I-beams and cast columns. The columns and beam flanges were unprotected. Each floor of this building was open from end to end, and all were stored with merchandise. The Beadle & Sherburne store and the building occupied by the Rochester Dry Goods Co. had brick walls and combustible floors, neither was in any sense of fire resisting construction, and both had window openings in front and rear.

The fire originated in the store of the Rochester Dry Goods Co. at about the point marked by the cross on the sketch plan. It swept through this building and, bursting through the rear windows, communicated with the stable of the Sibley, Lindsay & Curr Co. This stable contributed the flames to the wholesale store where, as already stated, they had an unobstructed path from end to end. At about the same time the flames from the Rochester Dry Goods store entered the Beadle & Sherburne store probably through the rear windows. This building in turn lent torch to the adjacent store of the Sibley, Lindsay & Curr Co. From the building last mentioned and from the wholesale building of the same firm the fire had practically free access to the Granite Building.

The Granite Building first showed fire in the basement and street floor at 7 a. m. At 8 a. m. the office furniture in the uppermost two or three floors was in flames, it having been ignited through the light shaft windows probably by the peak of the flame from the adjacent Marble Building. Shortly afterward the intermediate floors were on fire. The fire did not pass the Granite Building on the west and its spread north was stopped by the heavy brick fire wall between the Sibley, Lindsay & Curr wholesale building and the Cox Building. All the buildings except the Granite Building were totally destroyed; the wholesale store, with its brick arch floors carried by I-beams and columns, was quite as complete a collapse as any of the more combustible structures.

The behavior of the Granite Building demands more notice. Generally speaking the damage is greatest on the 12th floor and decreases from floor to floor until the 2d floor is reached. The street floor suffered scarcely less than the 12th floor. On all floors the damage was greatest on the east side and gradually decreased toward the northwest and southwest corners. On none of the floors were all of the combustible materials consumed, and on most of the floors below the 9th there were considerable quantities of unconsumed finish, furniture and furnishings. Glass was melted where the fire was hottest, but no evidence was found of fused metals of any kind. Considerable water was thrown into the building and particularly into the lower stories.

Referring to specific parts of the structure, it was found that the metal frame had suffered but little damage. The column fireproofing had been broken away in many places but always in small sections; no column was found which was as much as a quarter or one-third bare. The floor arches had lost their lower flanges in whole or in part on the 10th, 11th and 12th floors in perhaps seven out of every ten bays. Below the 10th floor this item of damage gradually decreased, but it was found on all floors. The 12th-story partitions were practically all wrecked, but those in the floors below were in fairly good shape as a whole. In general the partition failures were due to the burning out of the wooden strip at the top; this strip was gone in many of the partitions still standing and a slight push would overturn them. The marble wainscoting was practically all destroyed and in most cases had been ripped from the walls and broken into fragments. The marble stair treads between the street floor and the second floor were destroyed, but the slate treads of the stairways in the stories above were in good

Fig. 2. View of North Side of Granite Building Showing Openings for Bridge Connecting with Wholesale Building.

shape. Wherever the fire had been hot enough to take off the plastering, the beam flange slabs had also fallen.

The damage to the exterior walls of the building was very slight, but all windows and casings were destroyed. The steel rolling shutters, or fire stops, at the openings where the bridge from the wholesale building entered the Granite Building were destroyed and hung in ribbons.

Altogether the lesson to be drawn from the record of the fireproof building in the Rochester fire is its weakness against attack of flames from the outside and the necessity of guarding this weak point. The Granite Building would doubtless

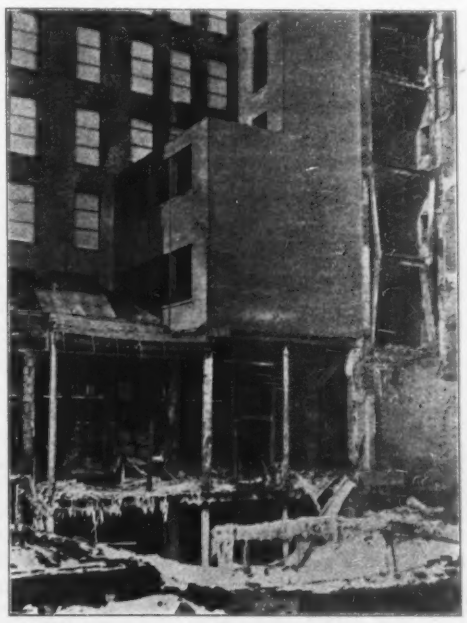


Fig. 4. View of East Side of Granite Building Showing Openings Connecting with Marble Building.

have been ignited in any case from the burning buildings on its east side, for the light shaft formed a veritable flue for the impinging flames and was thickly studded with windows of the weakest construction. Had the east wall been without windows, however, it is almost certain that the building would have been ignited through the half score of wide openings into adjacent non-fireproof structures. From the fire protection point

TABLE I.—Showing Adhesion of Various Shaped Rods to Concrete of Constant Composition—1 Part Cement to 3 Parts Sand.

No.	Section of steel.	Length, ins.	Perimeter, ins.	Load at failure.	Area of contact, sq. ins.	Load, per sq. in.	Average per sq.in.	Load per lin. in.	Average pr lin.in.
1.	½-in. square	6¼	...	.....	12.25	.....	...	.....	.....
2.		6¼	2.0	5,700	13.00	438 lbs.	432	877	864
3.		6	...	5,200	12.00	433 "	...	866	.....
4.		6¼	...	5,300	12.50	424 "	...	848	.....
5.	½-in. round.	6	...	4,600	9.43	488 "	...	766	.....
6.		6	1.571	5,000	9.43	530 "	512	834	804
7.		6	...	4,600	9.43	488 "	...	766	...
8.		5⅞	...	5,000	9.23	542 "	...	851	...
9.	¼-in. × 1 in.	6¼	...	4,900	15.63	313 "	...	783	...
10.		6¼	2.5	4,400	15.63	282 "	293	704	744
11.		6¼	...	4,800	15.20	314 "	...	784	...
12.		6¼	...	4,400	15.63	282 "	...	704	...
13.	¼-in. square	6¼	...	2,250	6.13	367 "	...	...	...
14.		6	1.0	1,800	6.00	300 "	369	...	...
15.		6	...	2,300	6.00	384 "	...	...	...
16.		6⅜	...	2,700	6.38	423 "	...	...	...
17.	"Ransome" ½-in. square	6½	...	12,200—7,900	.....*	...	...	1,215	...
18.		6½	...	12,800—8,000	.....*	...	...	1,325	1,250
19.		6¼	...	12,000—7,300	.....*	...	...	1,170	...
20.		6½	...	12,000—8,000	.....*	...	...	1,325	...
21.	¼-in. × 1 in. with ⅝-in. rivets thro'	6⅜	...	10,500	Rod broke at first rivet.				
22.		6⅜	...	8,000	Specimen split.				
23.		6¼	...	10,400	Rod broke at first rivet.				
24.		6½	...	9,800	Rod broke at first rivet.				
25.	Two ¼-in. rods twisted together.	6	...	5,100	Specimen split.				
26.		6⅜	...	8,000—6,200	Gave way momentarily at 6,200 and rods broke at 8,000				
27.		6⅜	...	5,400	Specimen split.				
28.		6⅜	...	5,700	Specimen split.				

*Note.—Scale beam dropped suddenly at the smaller load, but recovered itself and took more load until failure took place at the higher load.

of view these openings were almost inexcusable under any circumstance, and, when unclosed by doors, shutters, or any device for checking fire, as was the case here, their existence falls little short of criminal carelessness.

TESTS OF THE ADHESION AND INITIAL STRESS OF STEEL IN CONCRETE.

By Sam. W. Emerson.*

The existence and the amount of initial stress in steel rods embedded in concrete was made the subject of investigation about two years ago by the writer and Mr. George A. Peabody, students at the Case School of Applied Science. All the tests were made in the laboratories of the school, and they had for their object the determination of the existence and the amount of initial stress in embedded steel rods due to the expansion and contraction of the concrete. Incidentally tests were made on the adhesion of concrete to embedded steel. As the results of these tests contain matters which are of some interest to designers of concrete-steel they are briefly summarized.

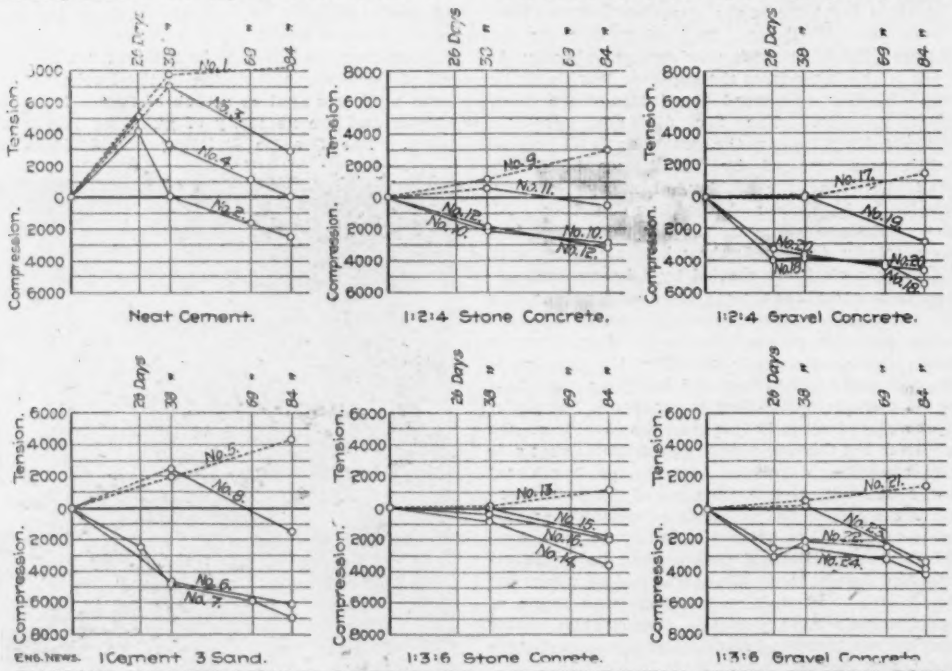
TESTS FOR INITIAL STRESS.—The work was carried out as follows: In each of 25 steel rods ½-in. square and 3 ft. 6 ins. long, two silver plugs were inserted 39 ins. apart. Across each of the plugs a fine scratch was made as a reference mark. One of the bars was selected as a standard, and the difference in length between the silver plug marks on it and on each of the other bars was carefully determined. This was done by means of a comparator used for comparing meter bars. One division on the head of the micrometer screw represented 0.481 microns, or a little less than 0.0005 mm.

The bars, except the standard, were then embedded in blocks of concrete 8 × 8 ins. × 3 ft. long. Half the blocks were allowed to set in air, the other half in water. At intervals, extending over a period of nearly three months, the embedded bars were again compared with the standard. The results are shown clearly by the accompanying diagrams. In these the changes which took place in air are shown by full lines, those which took place in water by dotted lines. It will be noted that, except the neat cement, all the specimens which set in air showed the bars to be shorter, indicating that the concrete had contracted in setting. In the specimens which set in water, the bars were all longer, showing the concrete to have expanded. The amount of stress in the steel due to this contraction or expansion was readily determined by Hooke's law,

$$\frac{S}{E} = \frac{T}{L},$$

or stress per square inch = $30{,}000{,}000 \frac{T}{L}$,

in which L = the length of the bar embedded in concrete and T = the change in length.



DIAGRAMS SHOWING RESULTS OF TESTS TO DETERMINE INITIAL STRESS ON STEEL RODS EMBEDDED IN CONCRETE.

*Osborn Engineering Co., Cleveland, Ohio.

TABLE II.—Showing Adhesion of 1-in. Square Steel to Concrete of Various Compositions.

Composition.	No.	Length, ins.	Area, sq. ins.	Total load at failure.	Load per sq. in.
Neat cement	1.	10⅛	40.5	14,000	346
" "	2.	10⅛	40.5	12,100	299
" "	3.	10	40.0	9,800	245
" "	4.	10⅛	40.5	9,000	222
1 cem., 3 sand..	5.	10¼	41.0	17,400	424
" " ..	6.	10⅛	40.5	15,800	390
" " ..	7.	10⅛	40.5	17,000	420
" " ..	8.	10¼	41.0	16,800	410
1 cement,2 sand, 4 broken stone	9.	10⅛	40.5	21,200	523
	10.	10¼	41.0	24,600	600
	11.	10⅛	40.5	24,200	598
	12.	10⅜	41.5	26,000	627
1 cement,3 sand, 6 broken stone	13.	10⅜	41.5	21,000	515
	14.	10¼	41.0	22,900	559
	15.	10¼	41.0	17,800	434
	16.	10¼	41.0	16,400	400
1 cement,2 sand 4 gravel	17.	10¼	41.0	19,400	474
	18.	10⅜	41.5	21,900	528
	19.	10¼	41.0	24,200	590
	20.	10¼	42.0	25,200	595
1 cement,3 sand 6 gravel	21.	10⅜	41.5	18,400	444
	22.	10⅜	41.5	22,000	530
	23.	10⅜	41.5	23,400	564
	24.	10⅛	40.5	21,200	524

After the last series of readings had been taken, specimens No. 1, which showed 526 divisions elongation, and No. 7, in which the contraction amounted to 446 divisions, were split open and the rods were removed and immediately remeasured. No. 1 had 11 divisions elongation and No. 7 had 20 divisions contraction, after removal, proving clearly that the changes were caused by the concrete. The small discrepancies of 11 and 20 divisions may have been due to a slight lag in the material or to inaccuracies in measuring.

The cement used was a well known brand, and care was taken to keep the room and specimens at a nearly constant temperature throughout the work.

A glance at the diagrams will show with what uniformity the specimens acted, all with two exceptions contracting in air and expanding in water. The discrepancy in the case of the two neat specimens was due to heating of the cement in setting. This heating was not noticed in any but the neat specimens.

It will be noticed that the specimens which expanded in water afterwards contracted when left in air. This would indicate that the volume depends upon the amount of water contained by the concrete.

This amount of the stresses is interesting, especially when it is considered that the observations show no reason for believing that they had reached a maximum or had ceased.

TESTS OF ADHESION.—A number of tests were also made to determine the adhesion of concrete to steel. Twenty-eight 6-in. cubes were made of 1 to 3 mortar, in each of which was embedded a rod of section as given in Table I. The rods were pulled out with a testing machine. From the results given in Table I, it would appear that the more symmetrical the shape of the rod the greater is the adhesion, and that this may be materially increased by twisting or mechanical devices.

To determine how the adhesion varies with concretes of various compositions, twenty-four rods one inch square were embedded in blocks of concrete 8 × 8 × 10 ins., and later pulled out in the testing machine.

From Table II. it appears that the richness of the concrete has but little effect on the adhesion, and that mortar has less adhesion than concrete. All the neat specimens failed by splitting, so that the results obtained from them are of little value.

In both sets of specimens the odd numbers were tested about 40 days after mixing, and the even numbers 40 days later. There is no noticeable difference in the values obtained at the two ages, showing that the adhesion reached its full strength quickly, and did not increase gradually with age.

Although the adhesion in the sixteen concrete specimens gives an average of 532 lbs. per sq. in. of surface in contact, the writer's experience has been that in practice it is not always safe to depend on this, but a mechanical bond should be used whenever possible.

RUSSELL WHEELER DAVENPORT.

Mr. R. W. Davenport, M. Am. Soc. M. E., General Manager of the William Cramp & Sons Ship Building Co., died at Philadelphia on March 2, after a brief illness. Mr. Davenport was born at Albany, N. Y., Nov. 26, 1849. He was the son of the Rev. James Radcliffe Davenport and Mehitabel (Whiting) Davenport, and a lineal descendant of the Rev. John Davenport, the founder of New Haven. His early education was obtained at Annapolis, Md., Burlington, N. J., Lausanne, Switzerland, Darmstadt, Germany, and New York city. He entered the Sheffield Scientific School at Yale in 1868, and graduated in 1871, receiving the degree of Ph. B. During the following year he was assistant instructor in the Chemical Laboratory under Prof. Oscar D. Allen. In 1872, at the close of the college year, he went abroad and spent a year in the School of Mines of Berlin University, and the following year among the iron and steel works of Germany, France and England. On his return to America in 1874 he became the chemist of the Midvale Steel Co., in Philadelphia, where he remained until 1888. During his last years there he was the manager of the works. In 1884, under his management, the first successful steel forgings were manufactured at these works for the modern style of built-up cannon, and for several years these were the only works in which this class of steel was made. In 1888, when the Bethlehem Iron Co. began to operate their gun and armor plate plant, Mr. Davenport was placed in charge of this part of the works, with the heaviest known mechanical appliances and machinery for producing the largest guns, armor plate and marine forgings. During the years from 1884 to 1901 he was in constant intercourse with the Army and Navy Departments in relation to ordnance and armor plate for the government, and, in the rapid growth of this new department of mechanical and metallurgical skill, he was recognized as a leading authority in the United States on these subjects, and as a chief factor in placing the United States quite at the head of all countries in the manufacture of steel for these purposes. In January, 1893, he was appointed Second Vice-President of the Bethlehem Iron Co.

In 1894 Harvard conferred upon him the degree of A. M., *honoris causa*, as a recognition of his acquirements as a metallurgist and of his services to the public in the work of building up the navy and in gun work for the army. His own university, Yale, paid him the same honor in 1895, at a time when the success of the country in the Spanish War depended largely on the ships whose armor plate and guns he had been mainly instrumental in creating.

In October, 1901, he resigned his position at Bethlehem and returned to Philadelphia. He spent a considerable part of 1902 in Europe. In June, 1903, he became General Manager of the William Cramp & Sons Shipbuilding Co., at Philadelphia, and entered upon the reorganization of its works.

Mr. Davenport's illness was very short; a heavy cold contracted at the works on Thursday, Feb. 25, developed into pneumonia on the following Sunday, and he died at Philadelphia on Wednesday, March 2.

On June 1, 1897, he married Cornelia Whipple Farnum, a daughter of Charles A. Farnum, Esq., of Philadelphia, and a granddaughter of Bishop Whipple. His wife and a son of four years, Russell Wheeler Davenport, Jr., survive him.

THE BIDS FOR FURNISHING CEMENT for the Tonto Dam in Arizona, opened on Feb. 29, have all been rejected by the Interior Department. The unusual circumstances in connection with the bidding were described in our issue of Feb. 25. The lowest bid submitted was that of the Denver Portland Cement Co., $4.81 per bbl. Considering the fact that the cement would have to be hauled over 1,000 miles by rail and 60 miles by wagon, this bid was a very moderate one; but it is believed by the engineers of the Department that the cement can be made at the dam site at a cost much below this minimum bid. The other bids submitted were as follows: Iola Portland Cement Co., in bags, $5.40; Pacific Portland Cement Co., San Francisco, $5.70; Atlas Portland Cement Co., New York, 150,000 to 250,000 bbls. f. o. b. cars at Mesa or Globe, Ariz., in barrels, $3.35; in bags, $2.90, adding 10 cts. for each bag furnished.

DOUBLE-COMMUTATOR MOTORS FOR MACHINE driving are the central feature of a "variable-speed" electric driving system which is being introduced by the Commercial Electric Co. of Indianapolis, Ind. Two armature windings are used in the motor, with a separate commutator for each; by proper combination of these windings by means of a controller a speed variation of one to four is obtained, maintaining the full load capacity at all speeds. The machine regulates very closely for constant speed on any one controller point. Twelve speed steps are given by the controller. At present the equipments are made in sizes from 2 to 20 HP. The speed range for the smallest size is 550 to 2,200 r. p. m., while for the largest size the minimum and maximum speeds are 250 and 1,000 r. p. m. Increased torque and efficiency over those shown by other types of variable-speed driving is claimed for the system.

THE BARIENTOS TUNNEL, the first double-track tunnel in Mexico, has been completed and trains are passing through on the Mexican Central Ry. and the Mexican National Ry. The cost of the tunnel was $335,000 (Mexican). The work was begun Feb. 25, 1903, under contract with G. Gordon Patterson.

THE GRAND TRUNK RAILWAY stockholders at a meeting in London on March 8, ratified the agreement with the Canadian Government for the construction of the

Russell Wheeler Davenport.

Grand Trunk Pacific Ry. from the Atlantic to the Pacific. Considerable opposition to the contract was voiced by some of the shareholders; but General Manager Chas. M. Hays, who was present at the meeting, stated that if the Grand Trunk refused this opportunity, rival financial interests would at once seize it, and without this transcontinental line the future of the Grand Trunk property would be most unpromising.

CENTRAL AFRICA IS ACCESSIBLE BY WATER, says Capt. L'Enfant, a French explorer. Capt. L'Enfant ascended the Niger, about 235 miles, to the mouth of the Benue River. This tributary is almost a second Niger and is navigable by steamers to Yola, for more than 500 miles of its course; following the windings of the Niger and the Benue a line of almost 900 miles of uninterrupted navigation is afforded between the ocean and Lake Chad. The French have growing commercial interests near this lake, but the cost of carrying supplies to this region has been almost prohibitive. They now propose to utilize the new route to its fullest extent, though, in its entirety, it can only be used by small boats for three or four months in the year.

THE MOST SERIOUS RAILWAY ACCIDENT of the week was a butting collision on the Alabama Great Southern Ry. at Kewanee, Miss., on March 8. A fast passenger train of the Queen & Crescent Route collided with an opposing freight for unexplained cause. Seven men of the train crews were killed.

A DYNAMITE EXPLOSION KILLED or injured 75 men, March 5, near Latrobe, Pa. Seven persons were killed outright and the others injured more or less seriously. Nineteen houses in the village of Kradenville were destroyed, and no house in the village escaped without damage. The dynamite magazine of the H. S. Kerbaugh Co., contractors on the Pennsylvania R. R., blew up, but from what cause is not stated in the reports.

THE AGGREGATE ANNUAL FIRE LOSS and losses of insurance companies in the United States in the past 28 years are tabulated as follows by the "Insurance Chronicle:"

	Aggregate property	Aggregate insurance
1877	$68,265,800	$37,398,900
1878	64,315,900	36,575,900
1879	77,703,700	44,464,700
1880	74,643,400	42,525,000
1881	81,280,900	44,641,900
1882	84,505,024	48,875,131
1883	100,149,228	54,808,664
1884	110,008,611	60,679,818
1885	102,818,796	57,430,709
1886	104,924,750	60,506,564
1887	120,283,055	69,659,508
1888	110,885,695	63,965,724
1889	123,046,833	73,679,465
1890	108,993,792	65,015,465
1891	143,764,967	90,576,918
1892	151,516,098	93,511,936
1893	167,544,370	105,994,577
1894	140,006,484	89,574,699
1895	142,110,233	84,689,030
1896	118,737,420	73,903,800
1897	116,354,570	66,722,140
1898	130,593,905	73,796,080
1899	153,597,830	92,683,715
1900	160,929,805	95,403,650
1901	174,160,680	106,680,590
1902	161,488,355	94,775,045
Totals	$3,002,630,171	$1,828,539,628

STATISTICS OF THE MERCHANT MARINE of the world in 1903, as given by the Bureau Veritas, are printed as follows in the Consular Reports for Feb. 29:

	Sailing vessels, 50 tons and over.		Steamers, 100 tons and over.	
Country.	Number.	Tonnage.	Number.	Gross tonnage.
Great Britain	6,839	2,196,443	5,929	13,966,972
United States	3,751	1,454,152	846	1,610,466
Norway	1,740	767,981	844	925,683
Russia	3,006	545,087	533	503,742
France	1,449	535,703	550	1,139,575
Germany	914	528,267	1,193	2,767,463
Italy	1,554	517,964	351	714,887
Sweden	1,515	278,445	594	473,051
Turkey	867	174,824	99	98,006
Japan	1,521	174,624	373	556,036
Greece	911	173,636	180	321,330
Denmark	797	126,135	341	477,087
Holland	704	104,722	304	608,153
Spain	576	94,294	403	712,804
Brazil	347	76,375	186	123,597
Portugal	278	60,736	23	35,633
Chile	111	51,886	38	62,742
Argentine Republic	163	40,540	93	73,128
Austria	129	29,118	224	540,354
Peru	56	24,690	3	4,784
Cuba	117	11,794	39	39,439
Mexico	50	9,165	27	17,200
Belgium	10	1,870	78	153,339
Uruguay	70	30,042	26	25,110
Total	27,705	8,066,205	13,381	26,158,358
Sailing vessels of less than 50 tons.	1,431	56,701	....	....
Steamships of less than 100 tons	....	....	3,814	646,200

A GERMAN SPARK ARRESTER FOR LOCOMOTIVES.

A new style of spark arrester in use on the State Railways of Mecklenburg, Germany, is described by the U. S. Consul at Berlin. It is designed to obviate the difficulty with wire netting due to the fact that the holes in the netting choke up and obstruct the draft and the netting rapidly burns out. The apparatus is described as follows:

It consists of a series of three grates set one above another in a square iron or steel frame of such size and form as to fit into the smoke chamber of the locomotive. The arrangement of the three tiers of grate bars is shown by the accompanying section:

Each bar is about 2 ins. wide by 1-10-in. thick, and is so set into the frame as to be held in place against any shock or pressure and at the same time to be free to expand or contract with changing temperatures. As shown by the diagram the middle tier or grate contains twice as many bars as the top and bottom tiers, and the arrangement of bars and spaces is such that while a free passage is secured for the gases of combustion, no spark or ember more than 0.16-in. in thickness can escape, and these are so small that they are self-extinguished within a few feet after escaping into the open air and cause no danger. This ingenious arrangement of the bars, together with the readiness with which they expand and contract under varying temperatures, acts to dislodge the adhering particles and prevents the arrester from becoming clogged, at the same time permitting a draft so open and free that the steaming capacity of the engine is said to be visibly greater than with any other type of spark arrester heretofore used in this country.

ENGINEERING NEWS

A Journal of Civil, Mechanical, Mining and Electrical Engineering.

Entered at the New York Post Office as Second-Class Matter.
Published every Thursday
at St. Paul Building, 220 Broadway, New York, by

THE ENGINEERING NEWS PUBLISHING CO.

PUBLICATION OFFICE, 220 BROADWAY, NEW YORK.
CHICAGO OFFICE, 1636 MONADNOCK BLOCK.
BOSTON OFFICE, 170 SUMMER ST.

FOREIGN AGENTS.

C. MITCHELL & Co, Snow Hill, Holborn Viaduct, LONDON.
RUDOLF MOSSE, BERLIN and HAMBURG, GERMANY.
JOHN F. JONES, & CIE, 31 Rue de Faubourg Montmartre, PARIS.

SUBSCRIPTION RATES: United States, Canada and Mexico, One Year, $5.00; 6 *months,* $2.50: 10 *weeks,* $1,00. *To all other countries in the Postal Union: Regular Edition. One Year,* $8.00; *Thin Paper Edition, One Year,* $6.75. *SINGLE COPIES of any number in current Volume,* 15 *cents.*

In requesting change of mailing address, state BOTH old and new address; notice of change should reach us by Tuesday to be effective for the issue of the current week. The number on the address label of each paper indicates when subscription expires, the last figure indicating the year and the one or two preceding figures the week of that year; for instance, the number 325 *means that subscription is paid to the* 32d *week (that is the issue of Aug.* 10) *of the year* 1905; *the change of these figures is the only receipt, unless one is sent by special request.*

ADVERTISING RATES: 20 *cents a line. "Want" and "For Sale" notices, special rates, see pages* 26-27. *New copy for standing advertisements should be received ten days in advance of publication; new advertisements, Monday morning. The pages containing "Want" advertisements are held open until Tuesday, and those with "Proposal" and "For Sale" advertisements until Wednesday at* 11 *a. m.*

The proposed New York salt-water auxiliary system, for better fire protection primarily, and for sewer flushing, street washing, snow removal, etc., as secondary considerations, is being seriously discussed. Objections to the use of salt water are many; but the most serious difficulty is that involving the effect of salt water upon the iron mains, valves and other fixtures. It is acknowledged that iron pipes exposed for a long time to the action of salt water, become soft and unfitted for use as water mains under high pressure, and when iron is combined with lead, brass or composition metal, salt water is liable to set up a galvanic action, more or less injurious to the combined metals. These are conditions that it is wise to study very carefully in advance of any new departure.

But for fire protection alone, why is it not possible to have an auxiliary pipe system of large volume, fitted with standpipes on high buildings, and operated by stationary pumps of high power—practically without having salt water in the mains at all, except in case of some great emergency? A salt-water auxiliary system of fire protection is comparable to the Texan revolver of storied fame. You don't want it often; but when you do want it, you want it badly.

If we eliminate the use of salt water for the other uses suggested and confine the special mains to fire protection only, we could have the following conditions: Lay a special system of mains adapted to resist heavy pressures in any section of the city that is in need of greater protection against fire. Connect with this system standpipes in tall buildings and at points of special danger; and along this system have street hydrants for hose connections. Then, somewhere on the water front, build your pumping station and equip it with high-pressure pumps, pumping directly into the special system of mains. But, allow only fresh water to stand in these mains as a rule; and for all ordinary fires, connect the pump only with the regular Croton water supply. In this way, there will be no salt water standing in the mains to corrode them or to injuriously affect the iron or the pipe-fittings.

The one other thing necessary, is to make a salt-water connection with the suction of the station pumps that can be opened when the fresh water fails to meet the demand and a greater volume of water is needed in case of a threatened dangerous conflagration. Then the fire-fighters have the rivers at their command as a source of supply. When the fire is out and the salt water is no longer needed it is not a very difficult matter to flush the mains themselves with fresh water, forcing out the water that is liable to do harm.

As an offset to the added expense of such a combined auxiliary system there are several great advantages over the present single line of fresh water mains. The city would have the important advantage of a pipe system especially designed for high pressures; and with the pumps in operation at the station, a single stream thrown upon a fire from standpipe or hydrant, would be equivalent in volume and power to that from a number of fire engines. There would be no delay in blizzard weather in reaching the danger point in a fire; for specially important buildings, a line of hose in position, a telephone message to the pumping station, and the turning of a valve, provide efficient means for protection. And when the fire assumes dangerous proportions, or when the fresh water supply fails from any cause, the same station pump can flood the district with an unlimited supply of salt water from the rivers. As an insurance against possible enormous fire loss, and as a means of adding to the power and volume of the present fire-fighting plant, some such scheme as here briefly outlined seems well worthy of trial.

The safe and proper design of grain storage elevators is a matter of much importance to a country which exports and deals in grain on such a scale as America. Yet, strange to say, there have hitherto existed practically no accurate data for the structural design of elevator bins. The series of careful tests on grain pressures made by Mr. J. A. Jamieson, of Montreal, and recorded on another page of this issue, puts at the disposal of engineers for the first time clear and comprehensive experiments in this field.

In particular, the series includes the first reliable measurements of grain pressure in full-size (actual) bins that have ever been published. Doubtless there exist other tests or individual observations of grain pressure in deep bins which have been made at one time or another, and we trust that they may be brought forward at the present time in order to place on record as much definite knowledge as possible.

It has been known that in the deep bins which in this country are universally used for grain storage, there is a head or depth of grain which, were the grain a liquid, would produce enormous bursting pressures. The actual pressures in elevator bins have never been determined from accurate experiment; but it has been well recognized that, while the traditional design of wooden bins would not withstand the pressure of an equivalent liquid in place of grain, yet it had by years of practical use been proved adequate for grain storage. Now that the desire to build grain elevators fireproof is leading to the use of new materials and methods of construction, it becomes absolutely essential to learn what are the actual pressures in grain bins. It is this that makes Mr. Jamieson's work so timely and of such direct practical value.

From a more abstract standpoint, of course, a knowledge of the forces involved in grain storage is desirable whatever material be used for construction, unless we are to be content to work forever with the rules of thumb developed in the past. Moreover, the subject of grain pressures has a wider interest for the light it sheds upon the forces in granular and semi-liquid masses generally. In this way it is related to the subject of retaining walls, a field only partially explored as yet. Without attempting to give any of the conclusions which may be drawn from Mr. Jamieson's experiments, we may note the important fact that grain in a storage bin behaves apparently as a perfect granular mass, with constant internal and external friction, i. e. without compressions and without cohesion.

This is involved in one item that may here be added to Mr. Jamieson's unusually complete paper. The author exhibits in detail a method of calculating grain pressure as developed from his tests. The method is capable of being summarized in a simple formula, and the pressure-curves obtained from this formula agree remarkably with the test curves exhibited in the paper. The formula is derived from a consideration of the weight carried by any element of the bin-walls, due to the friction of the grain bearing against it. A fundamental assumption is that for a given kind of grain there exists a constant ratio between the lateral (or horizontal) and vertical unit-pressure at all points in the mass. The assumption is well verified by the test pressures observed by Mr. Jamieson. If we write

V = vertical pressure of grain per square foot at depth h below the surface of the grain,
w = weight of grain in lbs. per cu. ft.,
f = coefficient of friction of grain against side wall,
k = ratio of lateral to vertical unit-pressure,
R = ratio of area to perimeter of horizontal cross-section of the bin, and
e = the base of the Naperian system of logarithms, we get the formula,

$$V=\frac{R\,w}{f\,k}\left(1-e^{\frac{-f\,k}{R}h}\right)$$

It should be said that this same formula was derived in 1895 by Mr. H. A. Janssen, of Hamburg, Germany, whose work on this subject is noted by Mr. Jamieson.

The formula given may be simplified by reference to some practical conditions. Wheat weighs 50 lbs. per cu. ft., and Mr. Jamieson finds that the factor k for wheat is very closely 0.6, while the friction-coefficient f for ordinary bin-walls averages about 0.4. We may therefore take the product k f to be 0.25. Further, for all square or round bins the ratio R is constant and equal to one-fourth the diameter. Using these values in the above formula gives,

$$V=50\,d\left(1-e^{\frac{-h}{d}}\right)$$

The term in parenthesis approaches the value unity as the depth of grain increases. The limiting value of the vertical pressure is, therefore,

$$\left.\begin{matrix}\text{Vertical pressure}\\ \text{in lbs. per sq. ft.}\end{matrix}\right\} = 50 \text{ times } \left\{\begin{matrix}\text{diameter of}\\ \text{bin in feet.}\end{matrix}\right.$$

It may be noted further that the term in parenthesis reaches the value 0.9 when the depth of grain equals 2.3 times the diameter of the bin. For all ordinary cases, therefore, we may use the limiting maximum pressure directly. The horizonal pressure, of course, is at all times 0.6 as great as the vertical pressure. As is shown by Mr. Jamieson, these pressures must be slightly increased if other materials than wheat are to be stored in the bin, the largest increase, 20%, being for peas.

It is a curious illustration of how slow even the simplest ideas are to find acceptance that while for centuries men have been separating gold from alluvial gravel deposits by water, it is only within recent years that it has occurred to any one to work the adjacent deposits in the bed of the stream, below the water level. Of course, the working of these deposits involves dredging, and, therefore, the exploiting of these under-water deposits had to await the development of the dredging machine, and then to further await the man of sufficient originality to apply the machine from its old use to a new one.

We publish in another column of this issue a paper on gold dredging in New Zealand, where this method of mining the precious metal has been more extensively applied and with greater success than anywhere else in the world. It is of interest to inquire the reason for this. Without venturing a positive assertion, we will hazard a guess. Our guess at the reason is, in brief, the conjunction of streams suitable for working by dredging and the right type of dredge, together with a mining community ingenious enough to adapt well-known means to desired ends.

There is no reason to suppose that streams with pay workings under their beds are more common

In New Zealand than they are in any other gold-bearing region having similar stream flow. In fact, since dredging was found so profitable in New Zealand it has been largely adopted in other gold-producing countries.

As to the chain-and-bucket dredge being the best type for dredging, experience seems to have fully settled that. The New Zealanders adopted it at first, not because they knew that it was the best type, but because it was the type of dredge with which they were familiar. Had American miners been equally familiar with this type of dredge it is quite within the possibilities that they might have tried it on the Feather and other gold-bearing streams of California and achieved success in gold-dredging before the New Zealanders.

The hope that concrete-steel piles will become generally available for engineering works lies largely in the presumption that they can be driven with hammer drivers as timber piles are driven. In this connection the record of experience in molding and driving reinforced concrete piles, which is published in this issue, should prove of interest to many engineers.

As in many other applications of concrete-steel we find that the greatest progress in the use of piles of this material has been made in Europe. A number of examples of concrete-steel pile foundations exist in England and on the Continent, and in nearly every case the piles were driven with hammer drivers. The only variation from regular practice in driving timber piles, was the use of a cushioned cap or a timber follower to receive the direct impact of the hammer, and the adoption of a heavy hammer with a short drop. The exact mode of procedure in each case is outlined in the article referred to above and can be ascertained by those interested. These examples of actual experience should go far toward begetting confidence in the practicability of concrete-steel piles in engineering construction.

It might be said that the first step has been taken in the American construction of the Isthmian canal at Panama. It is an all important step, and one indicative of American practice as contrasted with previous control in that region. This is the assignment by President Roosevelt of Surgeon J. C. Perry, of the public health and marine hospital service, to make a special study of sanitary conditions on the Isthmus. Surgeon Perry has already made an exhaustive preliminary report to Surgeon-General Wyman, chiefly relating to the City of Colon. He finds the conditions at Colon woefully unsanitary, with the larger part of the island a primitive swamp, covered with dense tropical vegetation and stagnant water. It is an ideal breeding ground for mosquitoes; and malarial fever, especially the pernicious forms of this fever, prevails throughout the year in all this section. All types of malarial fever are more frequent in Colon than in Panama. Surgeon Perry believes that Colon can only be made a healthy tropical city by filling in the entire island on which the city is built; and by the improvement of the water supply and the enforcement of sanitary regulations in the construction and maintenance of buildings of all types. As the swampy area extends back from the town for a distance of about fifteen miles and is from five to six miles wide, the filling process would be enormously expensive and consume time. But the recommendation is in the right direction. As at Havana when the United States troops first took possession of that fever-plagued city, so on the Isthmus, the first precaution to be taken at any cost is that having for its object the safeguarding of the health of those employed in constructing the canal. The first cost is great; but the ultimate gain is correspondingly great.

For the improvement of Panama, Surgeon Perry recommends the installation of a good water supply and a modern sewerage system. The latter is especially needed, as the existing drainage is of the most primitive character, and the soil itself must be saturated with the fever germs of past generations. But the conditions are not much worse than they were in Havana; and equally radical and intelligent effort should bring about at Panama equally good results.

Exports of manufactured goods from the United States in the month of January, as well as for the seven months of the fiscal year ending with January, show a larger total than has ever before been recorded in the same portions of the year. This official statement by the Department of Commerce and Labor is a very important indication of the solid foundation for future prosperity that is now being laid. The official totals are $38,213,352 worth of manufactured goods sent abroad in January, and $250,214,936 in the seven months ending Jan. 31. At the same time the prices of wheat and of cotton, our greatest staples of agricultural export, are at an unprecedentedly high mark, and as a consequence the value of current exports of agricultural products from the United States has also assumed record-breaking proportions.

These huge exports are rapidly reducing our indebtedness to foreign countries, and the effect in the long run will certainly be to create a surplus fund for investment in new enterprises. As we pointed out some months ago, an enormous amount of engineering works are planned by the nation, by municipalities and by the great railway corporations, and their progress only waits the accumulation of sufficient idle capital seeking investment. Under present conditions of international trade, we are drawing this capital to us from Europe at a rapid rate.

IF NOT AN AMERICAN ENGINEERING BUILDING, WHY NOT AN AMERICAN ENGINEERING LIBRARY?

The American Society of Civil Engineers, by a vote of 1,139 to 662 declines to join the other three great national engineering societies in accepting the offer of Mr. Andrew Carnegie to erect at a cost of about $1,500,000 a building in the City of New York for their joint occupancy. Whether this action is wise, or otherwise, time alone can disclose. But the vote cast against the proposition includes nearly one-half the active membership of the Society. It is therefore a representative one, and the majority very properly rules.

The deciding factors in arriving at this decision by the Civil Engineers were doubtless: the possession of a handsome building of their own, practically paid for; the disinclination to merge the fund representing this investment in a building where the American Society of Civil Engineers would be one of four tenants and have a corresponding fraction of control; and, finally, the belief—well founded or otherwise—that there would be a decided loss of prestige in abandoning the independent position won through years of patient and hard work. These sentiments were sufficiently strong to control the vote, and as representing the interests of the American Society of Civil Engineers alone, they were doubtless sincere.

For some years past, dating from the first attempt of the American Society of Civil Engineers to erect its present building, this journal has taken a somewhat broader view of this subject. We believed that there were many possible advantages to the whole profession of engineering resulting from a closer affiliation of the different engineering societies; and we welcomed the proposition of Mr. Carnegie as a means toward this end. At the present time engineers are interdependent on every work of any importance; they are compelled to act together professionally, each in his special branch; and no one man, however endowed, can know it all. It seemed to us that a hearty, intelligent and fraternal co-operation, such as could result from a centralization of headquarters, and the possibilities of closer personal contact, must result in permanent advantage to the whole engineering profession in this country. But we also foresaw that under any other than the conditions outlined, beneficial co-operation would be impossible; and it were then far better that the several societies remained apart. In other words, if any considerable portion of the membership of any one society were inclined to regard the other societies as rivals and competitors, and were desirous of securing for their own organization every possible advantage regardless of the interests of the other societies—if such conditions were to exist, then, to borrow a mechanical illustration, closer contact between the societies would only be productive of friction and destructive of harmonious and effective operation.

The letter-ballot was a fair means of testing the sentiment of the membership at large upon this question, and since it shows a large majority opposed to the project for co-operation, it is good evidence that a forced co-operation, not supported by the opinions of the members of the Society at large, would not have been wise.

As pointed out by us in the past, one of the great advantages of the four great engineering societies joining in one suitable building was the possible creation and maintenance of a great technical library in New York City; a library that is sorely needed, but does not exist in the United States. The collection of books, etc., in the House of the American Society of Civil Engineers is probably the largest; but this is very far from being a complete library of reference, even for the civil engineer. There would have been some gain in uniting the libraries of the four technical societies addressed by Mr. Carnegie; but this consolidation of libraries was one of the first suggestions voted down by the committees representing the several societies.

What engineers need in this country is a well-managed and fully-equipped library, which would be truly representative of the whole history and progress of Engineering Science in all its branches, here and abroad. Such a library should not only contain all important works upon this many-headed subject, but it should also gather and make accessible much material that is now being lost, and is yet sometimes very important. This is the engineering literature that appears in pamphlet form, the mass of which is very great and the bulk of which is sold as junk and re-ground into paper pulp. Yet these pamphlet reports, in many cases, are the only records of great undertakings, either proposed or accomplished; and a knowledge of their contents may sometimes be of vital importance. No individual can acquire or store them, and no existing technical library has the space to devote to them or the means to make their contents accessible. The same may be said of many of the so-called trade publications; and what engineer or society of engineers can find what is wanted in the mass of matter contained in the technical journals of the world, or in the proceedings of technical societies?

But were all the engineering books published and all the pamphlet reports printed, stored under one roof, the accumulation would be worthless to the engineer unless he knew what was under each cover and where he could find it. And herein lies the true value of the technical library here suggested, provided it were equipped with an ample and able library staff. With the contents properly indexed, these could be made available and useful to engineers remote from New York by a practically self-sustaining system of search and report by correspondence.

The structure itself in a convenient location, the collection of books, constant additions to the library, and its intelligent maintenance and management, would cost a large sum of money. No one society of engineers is rich enough to found or support such a library; and the contents of the library should be equally accessible to all engineers, no matter with what particular society they may affiliate. A library of the kind needed must be founded by an individual, and be well endowed. We know of no greater benefit that could be conferred upon engineers as a whole, or of a gift so likely to preserve the name of its founder in grateful memory.

No one can say what Mr. Carnegie will do, now that one of the four engineering societies that he proposed to benefit has declined to accept his magnificent gift. He may renew his proposition to the three remaining societies, and if he does, we sincerely trust that the library feature will not be overlooked. But if Mr. Carnegie should decide otherwise, we respectfully present for his earnest consideration the scheme of a great New York technical library. And he certainly could not erect a monument that would more fittingly express his obligation to American engineers and his appreciation of their work, or one that would do more lasting good to the entire profession of engineering in the United States.

LETTERS TO THE EDITOR.

How to Prevent the Bends.

Sir: Referring to your comments in reference to "Hospital Air Locks for Caisson Disease," on p. 187 of your issue of Feb. 25, you say "slow reduction of pressure in the air lock is the best preventative." I would add that it is the only one.

My own experience fully corroborates your statement. I have never had a single case in twenty years because I always keep the top door of the air lock sufficiently high above high water, as to be capable of holding one watch, the lower door being always at the deck. Do this and put in ¾-in. valves, then you will never require hospital locks nor an M. D. "The Captain."

36 Emerald St. S., Hamilton, Can., Feb. 29, 1904.

Proposed Rearrangement of the Brooklyn Bridge Terminals.

Sir: The Neff scheme for the change of Brooklyn bridge terminals, published in your issue of March 3, is not free from defects:

(1) The train movement in the Manhattan station is governed by the crossing between points H and J of Mr. Neff's sketch. On his lay-out it is not possible to give sufficient time for loading, get the trains through the crossing and maintain the schedule.

(2) Switching in his rearranged Brooklyn yard increases the time of the round trip, which again upsets the schedule for maximum train movement.

(3) The Neff lay-out requires the running of loaded trains through the crossing during rush hours, which alone is sufficient to condemn his scheme.

There is, however, a way of accomplishing what Mr. Neff aims to do. Julius Meyer.

115 Broadway, New York, March 7, 1904.

Sir: In an article on the Brooklyn Bridge Terminal Problem by Mr. S. S. Neff, and your editorial thereon in your last issue, it is assumed that the platforms of the Bridge Elevated Railroad may be extended to the end of the present tail tracks sticking out over Park Row. That, however, cannot be done legally, there being a permanent injunction existing against such an arrangement, the injunction having been granted at the instance of the owners of one of the adjacent buildings.

It would be necessary for the city to buy that property, whether it could use it or not, before the platforms of the tail tracks could be extended as proposed in Mr. Neff's plan. That plan is not new, and is only one of many proposed by those not conversant with all the legal, engineering, and operating difficulties existing in this complicated problem.

It is, nevertheless, true that it can be made the occasion of wasting a good many million dollars as proposed in the latest official plan. Moreover, the problem cannot be satisfactorily solved without taking into grave consideration the limber condition of the worn out Brooklyn Bridge, which does not permit of safely running trains over it ad libitum. I have referred to this limiting serious condition more than once before. G. Lindenthal.

45 Cedar St., New York City, March 8, 1904.

Materials Required to Make Different Classes of Concrete for Connecticut Ave. Bridge, Washington, D. C.

Sir: The following concrete preparations were determined by Mr. A. W. Dow, Inspector of Asphalts and Cements, and the writer.

Class A.

4 bags = 1 bbl. Vulcanite cement = 378.25 lbs.
= 4.5 cu. ft.
9 cu. ft. sand.
20.25 " " stone.
Yielded 21.4 cu. ft. concrete when rammed into place.

Class B.

1:2¼:6 (broken stone).
4 bags = 1 bbl. Vulcanite cement = 378.25 lbs.
= 4.5 cu. ft.
11.25 cu. ft. sand.
27 " " stone.
Yielded 27.66 cu. ft. concrete when rammed into place.

Class B.

1:2½:3:3 (3 gravel and 3 stone).
4 bags = 1 bbl. Vulcanite cement = 378.25 lbs.
= 4.5 cu. ft.
11.25 cu. ft. sand.
13.5 " " gravel.
13.5 " " stone.
Yielded 27.66 cu. ft. concrete when rammed into place.

Class C.

1:3:10 (gravel).
4 bags = 1 bbl. Vulcanite cement = 378.25 lbs.
= 4.5 cu. ft.
13.5 cu. ft. sand.
45 " " gravel.
Yielded 45 cu. ft. of concrete when rammed into place.

W. J. Douglas,
Engineer of Bridges, D. C.

Office of the Engineer Commissioner, District of Columbia, Feb. 18, 1904.

A British View of American Schools.

Sir: I notice in the February "World's Work," an interesting paper by Alfred Moseley, C. M. G., Chairman of the distinguished commission which visited this country last fall and made an extended examination of our schools and colleges. The following quotation from Mr. Moseley's article particularly concerns American engineers:

While in business in South Africa I had unusual opportunities to study the work of English and American engineers. The English engineers were much inferior. They slavishly followed conventional principles. They worked by the rule of thumb. They lacked initiative. They showed inability in a sudden emergency to grasp the situation confronting them, to put the right machinery to work to carry the task in hand in a practical way to completion. Often they attacked engineering problems with no more expert sureness and efficiency than any intelligent business man might have exhibited. The Americans, on the other hand, were alert and up-to-date, instantly equal to any occasion that might arise. In emergencies they knew at once what to do and what kind of machinery to use; and whenever they attacked a problem, after swiftly arguing the pros and cons, they carried the matter through in the straightest way with professional certitude of method. The English engineers had been poorly trained; the American engineers well trained. American business men whom I met were quite as alert as the engineers. A visit to the United States convinced me that the secret of the national efficiency lay in the American schools.

These advanced views of the Chairman of this Commission (which will issue a complete report during the coming spring), show the business-like incentive of the investigation and indicate anew the favorable impression that our American schools have made abroad. As far as instruction in engineering is concerned, Mr. Moseley's statement would seem good evidence that the practical courses of instruction by field, shop and laboratory methods, which are being developed so fully here in America, are of direct benefit to the practising engineer.

F. B. Sanborn.

Tuft's College, Mass., Feb. 24, 1904.

Courses of Instruction in Railway Engineering.

Sir: In your issue of Feb. 11 there appeared an outline of a proposed course in "Railroad Engineering," at McGill University, and editorial comments with reference thereto, which the writer agrees with in the main. However, I do not believe that the course as outlined will accomplish what it is intended to do, i. e., train men for the higher offices in railroad management, although any step toward special training of men in railroad work is in the right direction. It seems remarkable that a field employing such a vast number of men should have been neglected by educational institutions.

It has been the writer's experience that college graduates entering railroad work (in the engineering department) have not lacked so much in "railroad engineering" as they have lacked knowledge pertaining to the other departments. Which is, no doubt, the main cause why so few engineers ever reach executive positions.

Any course in "railroad engineering" which fails to take into account a study of the whole railroad field, in the writer's opinion, would be little or no improvement over the present course to be had at any of our engineering schools. It has been repeatedly stated and argued that railroading cannot be taught from books, but the knowledge must be gained by actual work on railroads. This I cannot agree with, for much can be taught in the schools.

A course in railroad engineering should include: The organization of a railroad corporation; Corporate powers; Railroad accounting; Statistics of traffic; Maintenance of way and maintenance of equipment; A study of the various types of locomotives and the services each type is best suited to perform; A study of car construction; The duties of officers; Signaling; Railroad history, etc.

The foregoing, together with the usual engineering course leading up to the degree of C.E., with possibly the engineering course curtailed so as to devote at least one full term to the subjects outlined above, would certainly be more profitable to the student who intends entering the railroad field, than the time spent on study of "location" and "construction."

Most engineers after leaving college who enter the railroad field, fill the subordinate position in the engineering department where they have plenty of opportunity to study "engineering" especially applicable to railroads. But so long as they remain in this department they have little opportunity of making themselves familiar with the work of the other departments. Hence it is specially desirable that some knowledge of the other departments should be had before entering the engineering department, which will enable the "railroad engineer" to understand intelligently what he sees going on around him daily, and to be fitted for promotion.

Yours respectfully, George F. Morse.

Muskogee, Ind. Ter., Feb. 27, 1904.

The Consideration of Adhesion Between Concrete and Metal in Calculating Concrete-Steel Beams.

Sir: On the subject of steel reinforcement in concrete beams it seems to me that one important point has been overlooked in the designing of beams for test and in the discussion of the results of the tests. The point referred to is that the adhesive value of the bar in the concrete should never be exceeded by the stress that the bar may be required to take. It is not enough that the ... adhesion up to the point of greatest stress be capable of resisting that stress, unless the stress and the ... value increase according to the same law. It is ... true that the stress in the embedded bar in a ... crete-steel beam varies as the bending moment, ... that the bar is not bent up near the supports ... of bending moments for a uniform load or for a ... ing across the span is a parabola, but the adhe... will be represented by a straight line. In order ... that the straight line does not fall within the ... at any point it should be tangent to that curve ... support, hence it will touch a point at a height ... ordinate of the parabola at the center of span. ... basis the adhesive strength, or skin friction, ... should, in a simple beam for uniform load, be ... maximum stress on the bar. Assuming that ... friction resisting the drawing out of the bar is ... per sq. in. and the ultimate strength of the ... 60,000 lbs. per sq. in., it would require a round ... rod to be embedded for 50 diameters in order ... ultimate strength of the bar just equals the holding ... of the concrete. On these assumptions the span should be 200 times the diameter of the bar, or the bar should not be greater in diameter than 1,200 of the span.

In Engineering News of Feb. 18 there is a ... on page 159 of a beam loaded uniformly, which has failed, apparently by the pulling out of the bar. The bar is evidently thicker than 1-200 of the span. The same fault in proportioning may account for the manner of failure of some of the tests made at the Massachusetts Institute of Technology, where the beams were loaded at two points, as indicated in the record of those tests in the same issue.

Yours respectfully, Edward Godfrey.

Monongahela Bank Building, Pittsburg, Pa., Feb. 24, 1904.

A Proposed Method of Computing the Strength of Concrete-Steel Beams.

Sir: Referring to the article in the News of Feb. 11, 1904, entitled, "A Simple Formula for Reinforced Concrete Beams," in which the author invited discussion, I wish to say I believe the formula to be correct, assuming as he does that the neutral axis is at the center of the beam. Having very few "facts at hand" I can enter into no continued discussion of the subject, but beg to be allowed to ask a few questions.

(1) Is it proper to consider the neutral axis of a reinforced concrete beam, of rectangular section, to be at the center of the beam?

(2) Does not the presence of the steel bring the neutral axis down to some line "c—d?" (Fig. 1.)

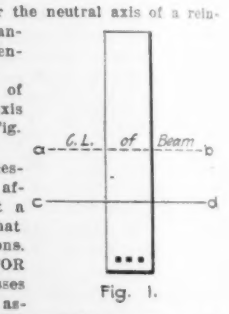


Fig. 1.

Assuming that my last question will be answered in the affirmative I wish to present a method of computing beams, that I have used on many occasions.

WORKING STRESS FOR STEEL.—As to working stresses for steel it is not correct to assume some safe value as 6,000 or 8,000 lbs. per sq. in.; but they should be calculated, taking into consideration the moduli of elasticity of the two materials, and the safe working stress for concrete in tension.

Assume safe working stress for concrete = 100 lbs. per sq. in.; E_c = modulus of elasticity for concrete = 1,400,000; E_s = modulus of elasticity for steel = 20,000,000.

Then the safe working stress for steel would be

$$S_s = \frac{E_s}{E_c} \times 100 = 2{,}100 \text{ lbs.}$$

NEUTRAL AXIS.—To find the neutral axis, assume the sectional area of steel to be replaced by an area of concrete equal in strength and concentrated at the center of gravity of the steel. We would then have a section such as is shown in Fig. 2. Calculate the moment of inertia of Fig. 2 about its gravity axis. The center of gravity of this new section will be the neutral axis of the reinforced beam.

Fig. 2.

STRESSES.—Compute the stresses by the moment of inertia formula. If the stresses found do not come within the specifications, assume different sections and refigure.

While the value of 2,100 lbs. for the working stress in steel may seem rather low, yet if the concrete in the lower flange of the beam is subjected to undue strains, imperceptible cracks will be formed. Later these, by action of the frost, would become larger and in time so injure the concrete as to make it of no value either for strength or as a protection to the steel.

Reinforced concrete has not been in use long enough to prove my statements, but I feel that my prediction will

certainly come true, if the ordinary high working stresses are employed, when steel is used in reinforced concrete beams.

Wm. T. Walker.

450 57th Place, Chicago, Ill., Feb. 16, 1904.

A Proposed Method for Reinforcing Concrete Beams Against Shear.

Sir: In the "Engineering Record" of Jan. 30, 1904, there appeared an article in defence of the use of concrete-steel construction. The article was well written and seemed to touch on all the methods that have served to bring this class of construction into unmerited disrepute, or at least to cause people who desire to adopt it to look with suspicion on its merits as a safe, permanent and economical substitute for wood or metal.

While the writer has great faith in the proper application of this form of construction, he has not yet had occasion to use it to any great extent in any design, and, therefore, can only form conclusions from reading, in the current technical journals, accounts of the experiences that others have had with it. The writer has noticed, however, that many of the articles that have appeared have practically agreed upon one point, and that is the low resistance against shearing that concrete possesses. To counteract this stress the following suggestions are made:

It will be noted that nearly all of the reinforced concrete beams that have appeared on the market have practically the forms shown in Fig. 1. This seems to take care of the tensile stresses to a greater or less extent, but makes no provision for resisting the shearing stresses, which are greatest at the abutments. To resist these stresses the writer suggests that metal web plates be fastened to the ends of the tension rods; that said plates be proportioned to resist the shearing and tensile stresses; that said plate be roughened on both sides, either by means of strips riveted on, or by ridges formed during process of rolling; that the joints at the ends of tension rods and plates have two or more pins or rivets in order to form stiff joints; that the usual stirrup irons be attached to tension rods on spaces left between plates. See Fig. 2.

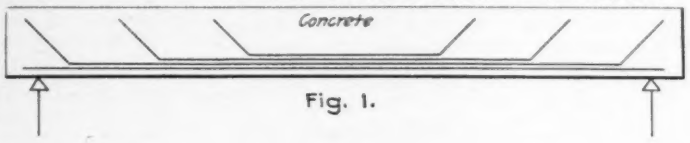


Fig. 1.

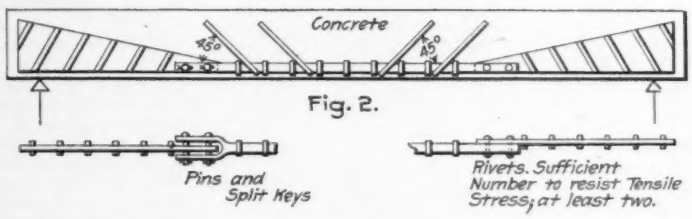


Fig. 2.

Perhaps it will be argued that the increased cost of manufacture on this plan would probably prohibit its adoption, if it has any merit. If, however, the plan will make safer the use of concrete-steel beams against failure by shearing, how will that compare with a slight increase of cost of construction, or rather of manufacturing the plates? The joints of plates and rods could be made with pins and split keys, or they could easily and quickly be riveted up in the field.

This idea is submitted to your readers to be "cussed and discussed" (more probably the former). It may have previously occurred to others who have experimented extensively with this form of construction, and it may have been discarded by them as "no good.' It, therefore, remains for those of us who have not been so fortunate as to have had any such experience to ask questions and to advance ideas and arguments (whether wise or otherwise) in order to be informed; and there is no other medium under the sun better known to the writer through means of which an idea, once advanced, is more quickly torn to shreds, and either approved, or condemned and ridiculed, and in no uncertain language either, than the column of your journal headed "Letters to the Editor."

The writer does not remember to have seen this idea advanced before. If it has any merit or originality the profession is welcome to it. If not, kindly let him down easily, as he has already plead guilty both to a lack of experience (in this particular instance), and to an earnest desire for correct information (at all times)!

Yours truly, H. F. Wilson, Jr.,
Assoc. M. Am. Soc. C. E.

First National Bank Building, Birmingham, Ala.,
Feb. 13, 1904.

A Criticism of Methods of Allowing for Shrinkage in Earthwork Computations.

Sir: Many of your readers will disagree with all four of the solutions to the earth measurement problem given in Engineering News of Feb. 25, 1904. (p. 120; Construction News Supplement.)

While under some possible, but altogether improbable circumstances, an embankment might be smaller than the excavation it came from, it is generally accepted as a fact that a recently built embankment is larger than the place it came from; and in order that there may be no doubt whatever as to what the engineer shall do in the matter there is inserted in some specifications this specific clause, which many of us will recognize as an old acquaintance: "When measurement is made in embankment a deduction for shrinkage will be made in making estimates, as follows:"

This shrinkage matter was fairly well threshed out in the courts some years ago, and the contention sustained that where a specific percentage for shrinkage was stated in the specification that percentage must be deducted whenever the pay quantities were measured in embankment, and while it might be professionally interesting to know, it was wholly a matter of indifference so far as the contract was concerned whether that material actually did shrink or not.

In the problem as stated the embankment contains by the cross-sections 100,000 cu. yds.

Deducting the 10% shrinkage leaves 90,000 cu. yds. of original material moved, of which 60,000 cu. yds. have been obtained from the roadway excavations, leaving 30,000 cu. yds. of borrowed material to be paid for, and not 50,000, nor 44,444, nor 44,000, nor 51,111 cu. yds.

If, therefore, the contractor actually got paid for 44,000 cu. yds. of borrowed material the company must have been "done" out of 14,000 cu. yds. of it.

Yours truly, John A. Fulton.

184 La Salle St., Chicago, March 2, 1904.

[Our correspondent presents a phase of the subject that did not enter at all into the problem given in our issue of Feb. 25. In that problem it was assumed as a fact that an embankment measures less than the excavation from which it is taken, and the specifications were drawn in accordance with that fact. Now our correspondent presents a new problem—one in which the embankment is supposed to be of 10% greater bulk than the excavation, and his solution of this new problem is correct; but it does not follow that all four of the solutions of an entirely different problem were incorrect.

As far as the assumptions made in the two problems are concerned, there is more room for argument. Some new embankments do have more bulk than the place they came from, but it is by no means "a generally accepted fact that a recently built embankment is larger than the place it came from." That is a generalization not at all in accord with the data on record. Whether a railroad fill when first made is larger or smaller than the cut, is dependent upon several factors, chief of which is the method of depositing the earth. The character of the earth itself is the second factor of importance.

Earth deposited with scrapers or carts is almost invariably less bulky in the fill than it was in the cut because the wheels and hoofs pound it down. Reservoir embankments when properly built invariably show a shrinkage of material during construction, due to the rolling or puddling or both.

Unfortunately very little is to be found in print to show the relation of cut and fill volumes of earth deposited from dump cars on temporary trestles; and it would be well if engineers, in charge of work where steam shovels and cars are used, would ascertain and put on record the rates of shrinkage or swelling of different kinds of earth. Our correspondent's letter serves again to emphasize the importance of making it very clear in a specification just what the unit of volume is upon which the specified "allowance for shrinkage" is to be made.—Ed.]

Precautions Against Typhoid Fever in Contractors' Camps.

Sir: Considerable space has been given lately in your journal to typhoid, and perhaps the following notes, although not from personal experience, may aid the cause. In 1897 the Crow's Nest Branch C. P. Ry. was built through the eastern part of British Columbia. There was severe suffering from typhoid; many laborers died, and many engineers and contractors were ill. I have personally interested myself while residing in that vicinity to obtain a "working knowledge" of typhoid.

Laborers came largely from "mill hands" at Ottawa, Ont. They were unaccustomed to hard pick and shovel work and came from an altitude of 100 to 200 ft. above sea level to work at 4,000 ft. Supplies were difficult to get into camps and contractors were not making money. Rough food was in consequence the rule. The men were not well housed, and there was considerable worry to get back East to families as things were not "going well."

It may be noted here that prospectors come in from the mountains with "mountain fever" and develop temperatures as high as 108°. These prospectors have been isolated from other men but their life is arduous and they worry.

I met a short time ago a physician from Detroit, and in discussing this subject he remarked that among 1,000 men brought into such work as that on the Crow's Nest Pass, 17 would be found to have typhoid. Perhaps it would be in such a mild form that they would never lose a day's work, although sick, sore and ill at ease. The excreta of these men is very dangerous to the well men in the camp.

The precautions against typhoid in contractors' camps which he proposed were as follows:

(1) Medical inspection that inspects, viz., Take temperature and pulse of new arrivals; if above normal, place them in suspect shack, but they may be allowed to work with other men. If high pulse and temperature does not continue, they are sent to main camp. Otherwise developments are awaited.

(2) System of latrines.—A wooden house over a pit. The house can be upset toward front or rear leaving pit open so that straw or twigs can be burned in it. A man is to be detailed to do this twice or thrice a week and to fill pit with earth from time to time and excavate a new one. Men must be compelled to use latrines and heavy fines imposed for infractions of regulations. A urinal must not be omitted. The ground surface if frequently dug over would suffice.

(3) Kitchens and dining shacks.—Place mosquito netting over all windows and use spring closed screen doors to prevent entrance of flies. Board shanties should have the cracks battened or covered with paper. Bread, cake and similar food should be heated in the oven before placing upon the table to sterilize germs transported by flies, etc. Of course the water supply of camps and any running water near points where work is going on must be guarded. The hot water barrel attached to cooking ranges requires emptying and inspection because the dishes are washed with the water.

Low vitality and worry induced by long hours of hard labor in the sun; ill-cooked, coarse food and lack of social life—consequent on fatigue and long hours—all have an influence on camp health, and men fall a prey to typhoid and other diseases more readily.

Ventilation of camps is usually bad, although pipes through the roof covered with netting would cheaply carry off the vitiated air and fumes of wet clothing.

At coal mines every camp has a "lean-to" in which are a couple of barrels for bath tubs. Every camp should possess this simple necessity with a small sheet iron stove, to encourage cleanliness, better work and less drinking and less trouble from drunkenness after pay day. All outbreaks of diarrhoea should bring a doctor to camp at once to investigate.

The Montana State report on Agriculture and Labor for 1902, contains reports on unsanitary camps well worth reading.

My informant also stated that although the Chinese use human excreta for fertilizing gardens, yet it is always allowed to ferment in stone jars (that is, I presume, it passes through the anaerobic process of the septic tank). I think he stated that typhoid was little known in China.

Will some one explain why horses, dogs, etc., do not contract typhoid though they drink and eat all manner of filth. Will the excreta of animals contaminate water so as to produce typhoid in human beings?

Milk carries typhoid. Do cows contract the disease? I have seen men drink from wells into which barnyard filth leached and contract no disease. Could the cows drinking this water transmit typhoid to the neighboring city by their milk?

I remain, sir, yours sincerely, C. R. Coutlee.

Inns of Court Building, Vancouver, B. C., Feb. 24, 1904.

(Our impression is that the typhoid germ finds no lodgment in the intestinal tract of other animals than man. If the contrary were the case, it is so frequent a thing to have pastures, barnyards, etc., draining into water courses used for public water supplies that typhoid would be vastly more prevalent than at present. Where milk is infected with typhoid, it appears to be invariably due to the entrance of the germs after the milk is drawn from the cow. The liquid is an ideal medium for the growth and multiplication of bacteria.—Ed.)

Problems in Laying Out Curves.

Sir: In Engineering News of Dec. 31 appeared an article by Professor Arnold Emch, entitled "Two Problems in Field Engineering." May I be allowed through your columns to ask Mr. Emch the meaning of this paragraph:

In the treatises on field engineering, this and similar problems are usually solved by a number of steps in which the usual instruments are used to get the geometrical solution. An analytic solution is possible, however, from which are obtained the final formulas given below, and which may be used in the field without any preliminary instrumental work.

What is meant by the "usual instruments," and what is the distinction between the "geometrical" and the "analytical" proof? How are these formulas better fitted for use without any preliminary instrumental work than the formulas of Philbrick, Searles, Shunk, and a score of others? As far as the field location is concerned, the same method can be found in almost any field book; in fact, it would seem to be about the first one that would occur to an engineer.

The second problem is one commonly found and consists in simply running a curve between two tangents and through a given point. All field books give very simple methods for finding the degree of this curve, and these methods give accurate results, and do not require large scale drawings to keep within "two feet" of the required point.

Mr. Emch's last paragraph saves the day.

Respectfully, "Subscriber."

Iowa City, Ia., Jan. 4, 1904.

Sir: I do not think many locating engineers will wish to adopt the solutions of the two field problems given by Professor Emch in Engineering News of Dec. 31. The ordinary methods are shorter and do not require the use of long and not easily remembered formulas or unfamiliar mathematical processes.

In the first problem, of a compound curve between fixed points on given tangents, proceed as follows: Run the first curve for the total angle and measure the offset, d, from the P. T. to the given tangent. Assume some radius R_1 which looks about right for the second branch of the curve. Then $\cos \triangle_1 = 1 - \frac{d}{R - R_1}$ (See Shunk's "Field Engineer," p. 98.) and this $\triangle_1$ is the angle of retreat along the circular curve to set the P. C. E. The second branch may now be run and the distance b from the P. T. to the required tangent point measured or, preferably, the semi-tangents of the compound curve computed and b found by subtraction. The computation of the compound semi-tangents involves the solution of one triangle only, the semi-tangents of the two branches being taken from a table.

Having obtained b by either means we have $\cot \frac{1}{2} \triangle_2 = \cot \frac{1}{2} \triangle_1 \pm \frac{b}{d}$ and $R_2 = R_1 + \frac{d}{\text{vers} \triangle_2}$ (See Searles' "Field Engineering," p. 118); $\triangle_2$ is the new angle of retreat for radius R_2, and $\triangle - \triangle_2$ the angle of the first branch of curve, $\triangle$ being used throughout as the total angle of the curve. The above supposes R to be the shorter radius. Reference to the pages of the field books quoted will show the changes necessary if $R > R_1$ or R_2.

The solution given for the second problem may be useful in paper location, but is impossible in the field. The ordinary method involves addition and subtraction, mostly, and the solution of right angled triangles.

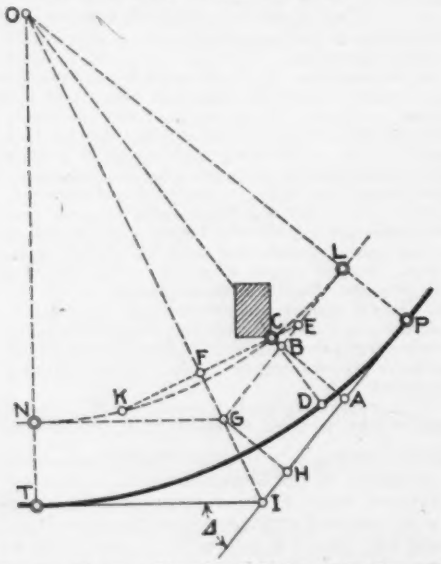


Fig. 1. Diagram Showing Solution of Problem II.

Referring to the accompanying Fig. 1, let P I and T I be the given tangents; $\triangle$ the angle of intersection; I O the bisecting line; C D = m the given minimum distance from C; L G and N G parallel tangents distant A B = L P = m from P I and T I; L C K a curve tangent to L G and N G and passing through C; C K a chord perpendicular to I O, and intersecting G L at E.

Measure A I, and A C perpendicular to P I. These two measurements with the angle $\triangle$ and the given distance m are all the data required for the solution of the problem.

$$CB = AC - m; \quad BE = \frac{CB}{\tan \frac{1}{2} \triangle}; \quad EC = \frac{CB}{\sin \frac{1}{2} \triangle};$$

$BG = AH = AI - m \tan \frac{1}{2} \triangle$; $EG = BG + BE$; $EF = EG \cos \frac{1}{2} \triangle$;

$CF = EF - EC$; $EK = EC + 2CF$;

Then $EL = \sqrt{EC \times EK}$; $BL = BE + EL$; $PI = BL + AI$.

This locates the P. C.

$$GL = GE + EL; \quad OL = \frac{GL}{\tan \frac{1}{2} \triangle}; \quad OP = OL + m = R,$$

the required radius.

It will be noticed that I have used $\triangle$, the angle of intersection as commonly understood, and not the supplement, as used by Professor Emch. Yours truly,

Geo. H. Tinker, Asst. Engr., C. F. & I. Co.

Pueblo, Colo., Jan. 12, 1904.

Sir: In your issue of Dec. 31, 1903, there is the solution of two problems in field engineering by Mr. Arnold Emch. These two problems can be solved analytically with much less work by precisely the same method.

I. "A Compound Curve Problem.—Given two tangents T_1 and T_2 of unequal length, their angle of intersection ϕ, and one radius R_1 of a compound curve joining the tangents, to find the length of the radius R_2 of the other branch of the compound curve."

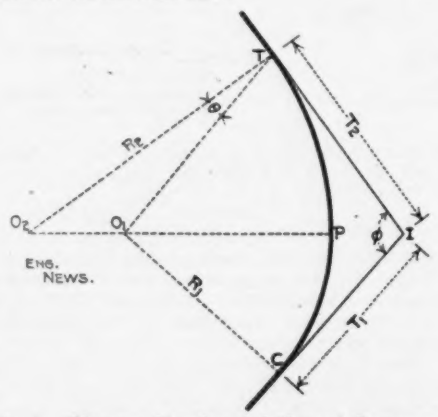


Fig. 2. Diagram Showing Solution of Compound-Curve Problem.

First find $O_1 T$ and the angle $O_1 T I$, either by solving the two triangles C T I and T O_1 C, or by a traverse. Now the angle $\theta = 90° - O_1 T I$ and we have a triangle $O_2 T O_1$, with one side $O_1 T$, the angle θ, the side $O_2 T = R_2$, and the side $O_2 O_1 = R_2 - R_1$; i.e., a triangle with one side, one angle, and the relation between the other two sides known.

Now (Loomis, Book 4, Prop. 13).

$(R_2 - R_1)^2 = O_1 T^2 + R_2^2 - 2 R_2 (O_1 T \cos \theta)$, or

$(R_1^2 - 2 R_2 R_1 = O_1 T^2 - 2 R_2 (O_1 T \cos \theta)$,

from which we find

$$R_2 = \frac{O_1 T^2 - R_1^2}{2 (O_1 T \cos \theta) - 2 R_1}$$

II. "Two tangents t_1 and t_2 include a given angle ϕ. At given distances from t_1 and t_2 is the corner C of a building. It is required to connect t_1 and t_2 by a simple curve having a given minimal distance from C."

Measure or compute the angle C I Z and the distance IC; then in the triangle I O_1 C we have known, $O_1 C = R - m$, and

$$I O_1 = \frac{R}{\cos \frac{\Delta}{2}} = R \sec \frac{\Delta}{2}$$

Since O_1 I bisects ϕ, we have

$$O_1 IC = \frac{\phi}{2} - C I Z = \theta;$$

we have a triangle, with one side, one angle and the relation between the other two sides known. Then

$$(R - m)^2 = IC^2 + R^2 \sec^2 \frac{\Delta}{2} - 2 R \sec \frac{\Delta}{2} (IC \cos \theta),$$

which on solving for R gives

$$R = \frac{m - IC \cos \theta \sec \frac{\Delta}{2}}{1 - \sec^2 \frac{\Delta}{2}} \pm \sqrt{\frac{IC^2 - m^2}{1 - \sec^2 \frac{\Delta}{2}} + \left\{ \frac{m - IC \cos \theta \sec \frac{\Delta}{2}}{1 - \sec^2 \frac{\Delta}{2}} \right\}^2}$$

Now this equation is a great deal more formidable looking in appearance than it really is in practice, for the angle θ and $\frac{\Delta}{2}$ are known and they can be eliminated in practice, greatly simplifying the equation.

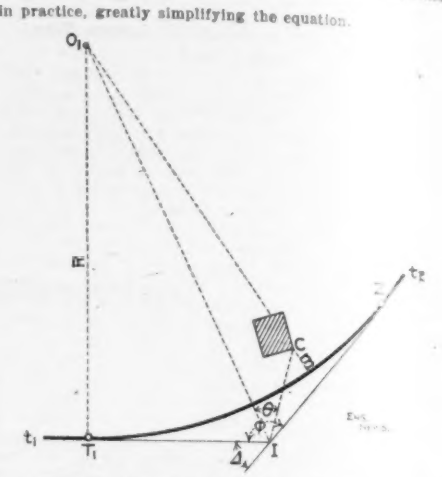


Fig. 3. Another Solution of Problem II.

Now I think these two problems are solved by the same method, and the solution is general for all that class of problems represented by plane loci, in which the unknown quantity is a straight line or an angle.

The solution consists of two steps:

First.—Enclosing the unknown quantity in a triangle;

Second.—From the data and the known relations existing in the locus, compute the functions necessary to solve the triangle.

The equation obtained by this process will in general be a simple equation of the first degree.

Respectfully, S. N. Daugherty.

City Engineer's Office, Seattle, Wash., Jan. 22, 1904.

(In accordance with our custom, we submitted proofs of the above letters to Professor Emch, who replies as follows:)

Sir: Thanks for your courtesy in sending me proofs of letters discussing my contribution in Engineering News of Dec. 31.

In reply to the criticisms, may I be permitted to restate the first paragraph of the article in question:

It should be one of the chief objects of mathematical research to test the value of its methods by their application to actual problems in the physical sciences and in engineering.

The proposed solutions of the two problems are two out of many results of this postulate which I have always upheld. That there are others, and, in view of their application to field work, possibly just as good solutions in existence, I knew before sending you my contribution. In fact, the second problem has been solved analytically by our class in Field Engineering, and it was because Mr. Duncan, Professor of Civil Engineering, had asked me for a geometrical solution that I proposed the given solution of the second problem. From this the fair critic will see that in publishing the two problems I was aware that I did not offer something entirely new or even startling to the engineer.

To judge from the last paragraph of his criticisms, "Subscriber" does apparently not expect any elucidation from the writer. It is, therefore, not necessary to reply to him in detail. Still, he has one passage which I should like to place in comparison with one of Mr. Tinker's statements. "Subscriber" says in connection with the first problem, "as far as the field location is concerned, the same method can be found in almost any field book; in fact, it would seem to be about the first one that would occur to an engineer." Notice that this location is based directly on my solution. Mr. Tinker writes: "I do not think many locating engineers will wish to adopt the solutions of the two field problems given by Professor Emch—the ordinary methods are shorter." . . .

As to Mr. Daugherty's solution, I am pleased to see his uniform method for both problems. Whether the actual computation by his solution of the first problem would be simpler than mine is not quite clear to me.

That the solution of all compound and reversed curve problems results from a uniform theory, a special consideration of bicircular quartics, I have shown in an article of the Kansas University Quarterly, Vol. V., pp. 99-108, as stated before. Yours very truly,

Arnold Emch.

University of Colorado, Boulder, Colo., March 1, 1904.

A BOULDER CONCRETE CORE WALL GROUTED with Portland cement mortar is described in a paper read at the 20th annual meeting of the Connecticut Society of Civil Engineers. Forms were built and small boulders of mixed sizes were shoveled in by one set of

men while at the same time another set of men shoveled in a thin mortar of 1 cement to 3 sand. The larger boulders were broken by hand to sizes not exceeding 7 ins. A core wall 2 ft. thick, 5 to 11 ft. high and 571 ft. long was thus built very rapidly. No account was kept of the materials and labor required. The work was done by the Hartford Paving & Construction Co., under the direction of C. E. Chandler and S. B. Palmer, engineers of Norwich, Conn.

A DECADE IN AMERICAN BLAST-FURNACE PRACTICE.*

By F. Louis Grammer,† M. Am. Inst. Min. E.

In order to appreciate the present condition of blast-furnace practice, it is necessary before enumerating the advances made during the past decade to give a brief discussion of the tendencies in the methods of administration as well as the conditions governing supremacy, for these factors have modified the aims of the manager.

Nowadays, the administration at some plants is such that the superintendent has become a train-dispatcher or a burden-clerk; and this is particularly the case in those plants in which the engineering duties have been divorced from the executive functions of the superintendent, and where the preparation of ores is made at the mine rather than at the plant. At such plants, usually consisting of four or more units, the proper feeding of the furnaces with a mixture, which the past has demonstrated will not make it ill, has become one of the superintendent's primary duties. The traffic management also is important and at several plants, running from 3,000 to 14,000 tons of raw material daily, excluding metal made, is equal in tonnage to that of many railroads. In addition to the traffic consideration, the cost and supplying of labor in these troublesome labor times, is properly deemed ample responsibility for the superintendent.

This distribution of duties is in line with the general tendency of the age to differentiate the duties of the laborer and the under executive, as well as to integrate between wider limits the responsibilities of the fewer and more powerful higher executives, has resulted in many benefits and some colossal errors. It has required the superintendent to be more a reader of events and men, while the engineer becomes more concerned with new devices to harness nature.

In the most powerful companies, this division of duties has usually resulted in good, but in those plants, like Saxe's razors, "made to sell," many mistakes have been made.

We can look around and see plants well arranged to make iron, but no iron mines to supply them. Others have fine mills, but no furnaces; others, no market. And so the whole decalogue of managerial sins, resulting from a bureaucracy or directorate of untrained iron men, can be run.

While largely due to perfected means of communication, the present state of affairs is indirectly traceable to the Bessemer process, whose Gargantuan appetite suggested the assembling of a large number of units near together. It affords a picture presenting marked contrasts to the time of Baron Stigel, whose return home, after an absence, was heralded by bonfires from the hilltops and the booming of cannon. It was a paternal management and included such diverse industries as charcoal-burning, road-building, farm-management, pottery-making and forge-running; a Pooh-Bah list of duties, picturesque, if not conducive, to the rapid development of an industry! His contract that a rose a year should be deposited on his grave forever, at a church in Manheim, Pa., in lieu of a ground rent, is not one that we imagine the iron masters of to-day would make.

The present conditions are even very different from the management under the Coleman family, so long a powerful and beneficent influence in the industrial world. Their manager was regarded as a family retainer with interests permanently identified with the family welfare. Under their employ the superintendents were as much engineers as managers.

The Bessemer process, by inaugurating the general policy that each process is the servant of the succeeding process, made the furnace the servant of the converter, and the converter of the rail-mill; and in the other direction the coke-oven and the ore-mine bore the burden of the furnace superintendent's criticisms.

A marked instance of this is told by a Mr. C., who ran the furnaces for a large plant in the middle West. At one time, he was being hauled over the coals rather roughly by the owner, because the mill was not getting the silicons it wanted. At last in petulance he said, "Are there no rights of the furnaces that the mill is bound to respect?" The answer received was final, "Not one."

Such a condition of affairs made the furnace superintendent's prestige depart, and his responsibilities are aptly described by one manager as being limited to the coke-barrow and the tapping-hole. On the other hand, the mechanical engineer and accountant came to the front.

As a result of those changed conditions we now find casting-machines introduced at plants where the highest mechanical efficiency is represented by a clever use of wedge, sledge and crowbar. We find automatic chargers used where the double-ring bell used so successfully by Mr. Firmstone and others should be used. We find the 100-ft. furnace treating magnetic ores and having a number of moves, which as managers and metallurgists we were taught to deplore. In short, if the advances became more rapid they were not always judiciously balanced. The pressure of fashion is so great that many do not consider whether it is personally becoming; in fact, local conditions are ignored.

On the strategic side we find, whereas formerly the ownership of a good ore-property and a good location near the market was supposed to be all that is necessary for manufacturing independence, now, one should own the cars, coke-ovens, coal-mines and frequently the railroad and the stone quarries, as well as the plant of your former purchaser.

Therefore, at the plant not independent of fuel supply, or whose fuel is expensive, fuel economy is the first consideration, while at the plant in a disturbed labor market, labor-saving devices are of paramount importance, and at the plant which controls the market, the size of the output is the first virtue. Obviously, with such a variety of aims the chief requirement of one plant may be of secondary importance to another.

In looking over the development of furnace-practice, four steps or incidents appear as the more important factors: (1) The use of waste-gas under boilers; (2) the heating of the blast; (3) the use of coke as a fuel; and (4) the use of Lake ores. Each of these steps has resulted in a doubling and trebling of the output which was possible before their introduction.

Of course, improved refractory materials and better engines were essential, as was also a knowledge of chemistry, but these influences should be regarded as secondary and logical sequences to the others. The better application of the knowledge classified under these four heads represents the development in America.

The earlier volumes of our Transactions are replete with papers concerning the analysis and fusibility of slags, scaffolds, frozen furnaces, titaniferous ores, dirty walls, sulphur in metal and a host of troubles resulting from a scattered and imperfect knowledge and an uncontrolled condition. As the facts became clearly known, men avoided trouble on the principle that "prevention is better than cure."

A decade ago lines of furnaces and cooling devices occupied the thoughts of the furnace world. Since then the advances made may be classified as follows:

(1) Conveyors and other mechanical improvements.
(2) Metallurgical by-products.
(3) Miscellaneous.

Exigency of space precludes all but a simple mention of many of the steps, as a division of duties has been attended by a flood of ideas developed along the avenues where the intrusive finger of modern accounting has shown that leaks existed and improvements could be made.

MECHANICAL CONVEYORS.—The use of Lake ores increased tonnage so rapidly that the simple handling of ore, coke and stone became a serious problem, and, as the properties became more and more under one control, the unnecessary moves of ore into boats to be unloaded onto docks, and to be again reloaded, were reduced. Steam shovels, like the Marion, Bucyrus and the Thew, were used to dig the ore out of the mines and to transfer it from the stock pile into the car. Messrs. Hulett, McMyler, Hoover & Mason, and the Brown Conveying Co., devised means of economically unloading the ore from vessels of many hatches. By means of these devices, and large piers at the shipping points, the hours when the boats were idle were minimized.

The rolling mill principle of keeping the passes of the rolls full of metal and the transportation virtue of keeping as many trains to the mile as is compatible with safety, was applied to the movement of the raw materials from the mines to the furnace. The steel cars reduce the cost of unloading by their steep bottoms, and these, with bin system, as at Duquesne, and car over-turners and bridges, as at Youngstown, represent the chief changes in the matter of handling raw material.

In moderate climates, where labor is expensive or troublesome, the devices have frequently paid well, and are sometimes necessary where the season for bringing the ore from mine to furnace is limited. Personally, I think that the skip-hoist, the last labor-saving step before the raw material enters the furnace, has not infrequently been introduced where the double-ring bell would have been better; this restriction, however, is not applicable to the general run of Lake ores.

Messrs. Walter Kennedy, M. A. Neeland and E. G. Rust designed skip-hoists which may be regarded as representing the three types. Mr. Walter Kennedy's descending bucket passes at the side of the ascending-bucket, and acts to some extent as a counterbalance; in the hoist of Mr. Neeland, one bucket only is used, and in that designed by Mr. Rust, the ascending- and descending-buckets pass over and under each other.

USE OF WASH ORES.—Mr. Firmstone showed me some charts of silicon and sulphur in basic metal made from wash-ores varying from 10 to 12% silica, which in their regularity and percentage of off-cast compared very favorably with the best practice in Pittsburg; the furnace using these ores was equipped with a double-ring bell. I believe that such regularity with material of this character will astonish most of the Pittsburg iron-makers.

VALVES.—In the question of valves, some attempt has been made to improve on the Mushroom & Berg valve-seat, the Spearman & Kennedy burner, and the cold-blast valve; save that they are made somewhat thicker and larger, they are substantially as they were a decade ago. The cutting action of Mesabi ore has suggested the multiplication of false seats and flanges on the stoves.

TAP-HOLE GUN.—The Vaughn gun makes the work of stopping the hole easier on the men and is especially satisfactory if operated by compressed air.

DIRECT PROCESS.—The extensive adoption of that very important link in the iron-plant—the direct process and the mixer—has suggested the undesirability of carrying a gang of specialized workmen all the week simply to carry out and break the iron on Sunday, when the converter is idle. This condition of practice has resulted in the invention of casting-machines.

CASTING MACHINES.—Mr. James Scott and Mr. Uehling have conjointly perfected the Uehling casting-machine, which is a monument to their perseverance in overcoming many obstacles. The Heyl & Paterson conveyor uses lamp-black in place of lime, and pressed-steel pans in place of cast-iron ones. I have always found the electric breaker at Duquesne, if used in connection with the iron-chills, less expensive and more satisfactory, though the iron cast in it is not so easily handled nor so attractive in appearance. Pig-iron casting-machines require more attention and are more easily thrown out of order than the electric breaker. Besides the above mentioned there are the Davies & Aiken pig-iron casting-machines, whose merits commend them to some. The iron-chills were necessary because of the rapid growth of the basic process in which sand and silica are most objectionable materials. In addition, the use of iron-chills saves the labor of molding the pig-bed in sand, and from them the idea was extended of making the runners and the skimmer of iron; the latter to a great extent doing away with boils.

SLAG-CAR.—The Weimer slag-cars, lined with iron thimbles, have been introduced practically to the exclusion of all others.

SLAG DISPOSAL.—In a few plants the slag is run into pits and granulated, and then lifted onto cars by means of cranes and orange-peel buckets. This method is very economical and is especially applicable when it is necessary to dump the cinder at a great distance from the plant, more especially if it can be utilized for manufacture into cement. One disadvantage of granulating the slag is that it may cause annoyance by creating a cloud of steam at the time of casting the iron. In some plants the slag is run into dishes, or metal pans, working on a conveyor, and after it cools it is broken up and carried away for use as railroad-ballast, a method which is advisable if the slag is non-slacking.

RECORDING-GAGES, ETC.—The introduction of more recording-gages for steam, air-blast, vacuum-pressure and temperatures of blast and escaping furnace-gases, marks the advance of furnace practice into a state of better control.

The extensive introduction of the direct process and the pig casting machine has, in a few cases, caused the abandonment of the cast-house, except a small building which is required to cover the cinder and the iron in their passage to the ladles.

DUST-POCKETS.—The use of Mesabi ores has made an increase in the number of dust-pockets on the gas main. These pockets as well as the dust-catcher are now suspended above a track, so that when the pockets are dumped the dust will fall into the cars which have been run underneath them.

LADLE DRYING.—The iron ladles, in the absence of natural gas, are frequently dried out by burning the blast-furnace gas brought to them in a small flue.

GAS-FLUES.—In a few American plants the gas-flues are not lined with brick, but the great majority use cheap fire-brick and do not copy foreigners in this practice.

At some places, as at Braddock, a satisfactory water-seal valve is used to isolate a furnace from others on a common system of gas-flues, for which purpose the Rothoff valve is extensively used.

GAS-MAINS.—Almost all gas-mains are now overhead, and underground mains are avoided. Not only is the steam system universal in the modern plant, but the tendency is to make the gas-flues universal. If one of the furnaces is cold and its gas, therefore, not suited for stoves, the gas from the three other furnaces in the system will help to maintain the stove heat on the one that needs it; in a similar manner the gases from the many furnaces tend to keep the steam-pressure regular.

BOILERS.—The introduction of water-tube boilers marks the further attempt to obtain the full power possibility of the escaping gas; the Babcock & Wilcox, the Stirling and the Cahall being those the most generally adopted. The numerous water-softeners, generally based on the principle of having the carbonates precipitated by lime and the sulphates decomposed by soda, have enabled water-tube boilers to be more extensively introduced. The

*Slightly condensed from a paper read at the Atlantic City meeting of the American Institute of Mining Engineers.

†2422 Madison Ave., Baltimore, Md.

old idea that because there is an excess of gas and on account of the ease with which scale can be removed, cylindrical boilers should be used, has passed away.

USE OF COMPRESSED AIR.—Compressed air in place of steam is being quite extensively used for such purposes as the operation of the furnace-bell and the mud-gun. It does away with the danger of burning the men and of having the water condensed around the tapping-hole and freezing around the furnace-top.

STEAM-PRESSURE.—The economies in the use of blast-furnace gas have become so extended that we now economize also on the steam obtained from the gas. In place of the 80-lb. pressure of 12 years ago, and the 60-lb. pressure of a decade earlier, we now use from 120 to 150-lb. steam-pressure in connection with compound engines, condensers and feed-water heaters. The engines are of heavy frame and the air-valves are positive acting, which gives a higher efficiency of delivery.

Without the modern engine-equipment it is probable that the present phenomenal outputs could not have been attained. Despite the fact that a finely divided ore is reduced more rapidly than a lumpy coarse ore, its use requires a greater blast-pressure, and a larger volume of blast, else its fineness will not be taken advantage of; therefore, if the increased pressure and volume could not be supplied, the output would be smaller than when using lump ores.

I remember visiting a plant where this fact was not appreciated by the owner. It had too many engines and too many boilers, but the furnace could not get a sufficient quantity of blast to satisfy its hearth area. The steam-pressure was only 60 lbs. per sq. in. and the blast-pressure only twelve.

The Southwark Foundry & Machine Co., the E. P. Allis Co., the shops of the Tod Engine Co., and, latterly, several others have met the new conditions. Not, however, without some tribulation, for a 100-ft. furnace requires more work to be done than a 90-ft. one, this latter dimension is, in my opinion, metallurgically more desirable.

The hoist-engines in the majority of cases remain extravagant users of steam. Several plants have introduced electricity to operate the hoist.

In a few plants happily designed, where the height of the furnace is not over 90 ft., there is a surplus of steam obtainable from the furnace-gas after supplying the power-demands and the stove-demands. These plants sell the surplus steam to the adjacent mill. In many other plants the increased blast-pressure resulting from the excessive height of the furnaces or other conditions have nullified the steam-economies resulting from the improved machinery.

In some instances it has been deemed advisable to use the surplus gas to attain a higher temperature of blast (with the view of having a lower fuel-consumption), rather than to sell it to the mill.

HOT-BLAST STOVES.—In hot-blast stoves, the bottom-rings are now made of such a height that the riveting on of door-frames, ports and branches is done without crossing a seam. These plates are also made very much heavier than formerly because of the higher blast-pressure now used. Stoves of the central combustion-chamber type seem to be gaining in popularity, and brick specially shaped for the checker-work continues to be extensively used.

REFRACTORY BRICK.—The brick manufacturer has been fully abreast with the requirements, and supplies a cheap brick for the ladle-lining, and a brick free from iron suitable to withstand abrasion for the furnace top, and one free from alkalies and bases for use with high heats. Prior to the year 1890 a blast-furnace campaign lasted from 18 to 30 months, now it exceeds eight years, and several furnaces have produced more than a million tons of pig-iron with one lining, which has reduced the relining charges per ton of iron produced from 50 cts. to less than 15 cts.

SHIELDS.—A number of shields and protectors have been devised to protect the lining of the upper part of the furnaces from the abrasions of the stock rolling off the bell against the top walls. Of those that I have seen, the best is a suspended sheet of heavy rolled steel, which was introduced by Mr. Firmstone at one of his plants. As used by him, an annular opening extending completely around the furnace top was obtained for a gas outlet.

WATER-COOLING.—At many plants having a small supply of water, a wooden waterfall is used for the purpose of cooling the condensing water for repeated use.

BY-PRODUCTS.—There has been a rapid growth in the use of slag-cement which is placed on the market under the name of "Puzzolani," a name derived from the natural cement rock of Italy. Slag-cement is used as a substitute for Rosendale cement for purposes not requiring the highest degree of reliability. Among other places, it is manufactured extensively in Chicago, Ill., Youngstown, O., and at Sparrow's Point, Md. The process of manufacturing slag-cement has been frequently described, and is being so improved that its consumption will probably increase.

In charcoal manufacture, ammonium acetate and wood alcohol are obtained as valuable by-products, and the by-product coke-ovens yield ammonia, tar and gas. Each of these subjects is worthy of an individual monograph, especially the by-product coke-oven, with its promised economies, both in fixed carbon, yield and labor.

FLUE-DIRT.—The loss of flue-dirt, in the treatment of mixtures containing a high percentage of Mesabi ore, has suggested the use of gas-washers and briquetting-machines. The Steece and the Roberts washers are those in most general use. The Henry S. Mould briquetting-machine has been introduced at several plants to recover the ore that has been blown over from the furnace. The loss through flue-dirt can unquestionably be lessened by the study of the conditions outlined in my recent paper in our Transactions, "Flue-Dirt and Top-Pressure in Iron Blast-Furnaces."

SAVING OF GAS.—The introduction of a double bell, preventing the issuance of gas during the lowering of the charge, has resulted in a saving of from 10 to 15% of the gas. At several plants using a single bell the average time during which the bell was open exceeded 2 hours and 40 minutes.

BLAST-FURNACE WORKING.—Impressive as is the metallurgical practice in America, it exhibits inventive ability less than natural resource. We owe more to the regions named after the emissary of peace, Pere Marquette, and the tribes he went out to civilize and Christianize (Menominee and Gogebic), than we do to original research. It is true we have the Uehling pyrometer of American origin, which is an instrument of great precision and of great value to the furnace-man. Our records, however, are characterized by bold application rather than new ideas.

Our high furnaces do not reflect great credit on their designers, though in justice it should be said that most furnace-men were not in favor of 100-ft. heights. I have personally inspected more than sixty furnaces, and I find that the fuel-consumption, other conditions being equal, is lower on furnaces of from 70 to 80 ft. in height than on furnaces exceeding 90 ft. While Dr. Egleston's records, ending in 1896, do not include any very high or very large furnaces, the best fuel-consumptions he quotes are in furnaces in the neighborhood of 75 ft. in height.

With very irregular ore or fuel and very expensive coke, it is a question whether a very large output per furnace is desirable. A bad cast if small is more easily taken care of by the mixer than a very large cast. The principal reasons, however, why our fuel-economy has not improved (in fact it has gone backward) are as follows: The coke-ovens have been insufficient to meet the increased demand, and in order to increase production, the time of coking was shortened, which has resulted in a poorer quality of fuel. Then again the shortage of cars has caused many furnaces to be repeatedly banked, which has consequently increased the coke-consumption. Many cokes formerly considered too high in ash, and therefore low in carbon, have been put on the market. Finally, the furnaces mixtures used have been leaner.

The stove heating capacity has not kept pace with the blowing-power, consequently lower temperatures of blast were used, resulting in a higher fuel-consumption. In several instances it was considered desirable, in view of a brisk market and large profits, to use the furnace-gas for making more blast, rather than to save the coke, by using a high temperature of blast.

Generally speaking, the silicon requirements for Bessemer iron have been lower, depending upon the location of the plant and other conditions. The average percentage of silicon may be taken at 1.1% in summer and 0.9% in winter. The lowering of silicon demands has been in the furnaceman's favor. A brisk market also has lessened the severity of the demands of the mill in sulphur. I think in some quarters there is a greater tolerance of sulphur than existed 10 years ago. In other quarters the metal must be remelted if it exceeds 0.05% sulphur.

Owing to the improved preparation of raw material, the furnaceman is supposed to be able to keep the sulphur down without the use of manganese, and as high manganese percentages, through the great spluttering they occasion, prevent the forcing of the work in the converter, this element is a greater detriment in iron-ores than it was in the beginning of the past decade.

The increased purchase of ore containing a higher phosphorus-content has accompanied the rapid extension of the basic open-hearth steel process. It is not unusual upon the shutting down of the converter on Saturday afternoon, while the metal is being run into the chills or through the pig casting-machine, to put a basic mixture in the furnace, a procedure which is especially desirable if the furnace capacity of direct-process metal is sufficient for the converter capacity and need not be supplemented by remelting the Sunday's product in a cupola-furnace. The direct process, with the great advantages afforded by the closing down of the cupolas, has been greatly extended, and molten metal in Pittsburg and Cleveland is carried in 20-ton cars for more than a distance of five miles.

The use of multiple tuyeres has not always been attended with satisfaction, and a more conservative estimate of their benefits now prevails.

The drying of furnaces preparatory to "blowing-in" is now much shorter in time than was the practice a decade ago, many thinking a week quite sufficient. During the blowing-in period the burden is now increased more rapidly, and the quantity of wood used is very much less than formerly. I know a very successful operator who uses no more than a cart-load of wood for blowing-in a large furnace, and a few who light the fires in starting by means of red-hot iron-bars introduced through the tuyeres, while the blast is on. Ignited charcoal also is satisfactorily used by some to blow it through the tuyeres during the starting of the blowing-in. The hot-blast stoves can now be heated more previous to starting than was formerly practicable, due to the use of natural gas or the universal gas-main.

A saner treatment of the tap-hole now prevails, due to the recognition that an exceptionally large product for a single day means little, and as a consequence the last portion of iron in the crucible is not drawn by long prolonged blowing at the tap-hole. The blowing at the tap-hole leads to break-outs, on account of the heating up of the furnace front.

The blowing away of furnace bell-and-hopper slips, which frequently occurred after the introduction of Mesabi ore, is now unusual. This usually disastrous irregularity was then attributed to a so-called dust-explosion, but I think this assumption is wrong, and the irregular working, even with high percentages of Mesabi ore in the charge, can be obviated. The proportion of Mesabi ore used in the ore-mixture has, in exactly a decade, increased from 25 to 100%, a furnace in Pittsburg having been blown-in recently with the ore-mixtures composed entirely of Mesabi ore.

While the ingenuity of American metallurgists savors less of the lamp than that of European engineers, still in the recognition that fine ores are quickly reduced in the furnace (analogous to the manner in which salt enters more readily into a solution if the more finely divided, and its corollary, that a finely divided material must be given a large volume of solvent in order to dissolve it rapidly); and by applying this principle American engineers have acted with great promptness and received enormous returns.

The introduction of gas-engines at the Buffalo plant of the Lackawanna Steel Co. has marked an important epoch in blast-furnace practice. By eliminating boilers, and thus combining the duties of boiler and blowing-engine, economies are promised amounting to 20%.

Through the courtesy of Mr. Wehrum, formerly the general manager of the Lackawanna Steel Co., the following data on the company's gas-engines have been contributed:

The distribution of the units of horse power of blast-furnace gas-engines installed in Europe prior to February, 1902, was: England, 600; Italy, 1,800; Russia, 2,230; Austria, 2,840; France, 7,400; Belgium, 7,600; Luxemburg, 15,400, and Germany, 44,665; making a total of 82,535 HP.

Blast-furnace gas in gas-motors is 37% higher in efficiency than that used to produce steam, and I estimate that the engines introduced at the plant of the Lackawanna Steel Co. under my administration shows an economy of fully 300% more than that of the single-condensing steam blowing-engines, which is equivalent to a saving of $12.50 per HP. per year, by the introduction of blast-furnace gas-motors. Gas-engines are now installed and in operation at the Buffalo plant of the company to the extent of some 5,100 HP.

The above-mentioned quantity of horse-power (82,535) has since been increased to 297,050, which is distributed among the various gas-engine makers, as shown in Table I.*

TABLE I.—Blast-Furnace Gas-Engines (Exceeding 200 HP.) Completed or in Course of Construction Oct. 31, 1903.

Name of maker.	Deutz.	Koert-ing.	Nuern-berg.	Oechel-heuser.	Cock-erill.	Total.
No. of engines.	123	70	57	41	116	407
Total HP.....	49,225	83,475	61,350	27,400	75,600	297,050
Average HP....	400	1,192	1,075	667	652	730

For those who wish to study this subject further, I refer them to the intersting brochure published by Mr. Wehrum.† Considering the fact that about two-thirds of the gases are now used for the production of power and one-third for heating the stoves, the subject is well worthy of study.

Mr. Uehling‡ makes a statement, that for each ton of pig-iron produced per hour there will be available 800 HP. for sale or for use in connection with the rolling-mills connected with the blast-furnace plant, and Mr. F. duP. Thompson, who assisted Mr. Wehrum at the Lackawanna Steel Co.'s plant, is of the opinion that 500 HP. per ton of pig-iron produced per hour would more nearly approach practical working.

The blast-furnace has always been regarded as representing a high degree of efficiency. In the direct process, the heat contained in the molten iron has been saved, and doubtless ere long the heat of the molten slag also will be utilized. But it is in the line of using waste gases that our signal economies have been scored. First, in using it under the boilers, then, in using it under the stoves, then, in sealing the top of the blast-furnace with a double bell, then, in selling the excess waste gas to the mill in the form of steam, and now, after continuously demanding more from it, we hope to receive more by the introduction of gas-engines.

In the Metallurgical Congress, which I suppose will form a part of the Louisiana Purchase Centenary, it will be appropriate to record the progress of that plant of unrivaled natural resources, viz., the Colorado Fuel & Iron

*"Iron Age," Jan. 14, 1904.

†Studies of Blast Furnace Gas and Its Most Economical Use, Scranton, 1900.

‡Stevens' Institute Indicator, January, 1903.

Co., situated in what was then the great American Desert, and what is now one of the greatest coal-fields and ore-deposits of the world.

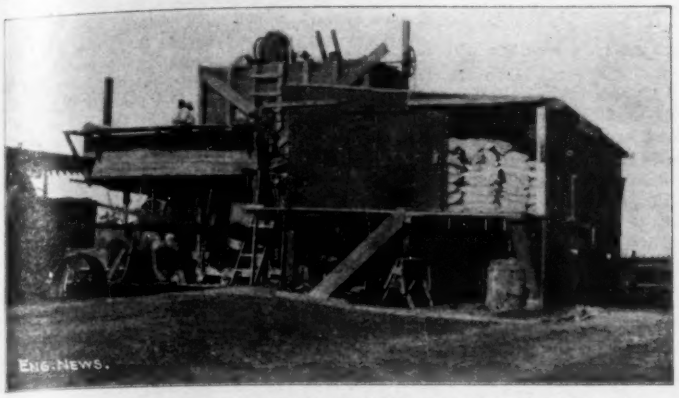


FIG. 1. CONCRETE MIXING PLANT FOR STREET WORK.

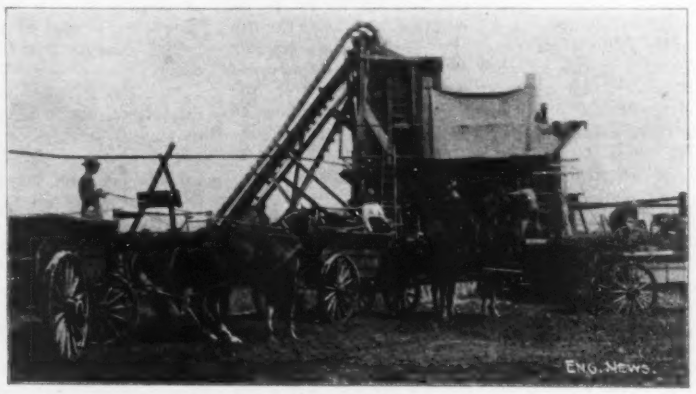


FIG. 2. LOADING DUMP WAGONS WITH CONCRETE.

Although our coke-consumption remains between 1,750 and 2,100 lbs. per ton of metal produced, our daily output per furnace has jumped from 350 to 500 tons and more in a decade, and the total yearly output of pig-iron, according to Mr. Swank, has grown from about 8,000,000 tons to 18,009,252 tons in 1903. This rapid increase in the production can be understood when it is known that one 500-ton furnace has been erected and produced iron within one year and one day after the pick was first driven into the ground.

In the iron world it has been proven that high wages need not mean increased cost of production. The region between the Great Lakes and the Connellsville coal-field is still regarded as being a section where the most advantages are found, possessing easy access to high-grade cokes, the best ores, the most skilled and ambitious labor, the greatest mechanical ingenuity and the best markets. Colorado and Alabama also hold strong positions.

While the decade has recorded the abandonment of many plants economically unfit, it has been a period of great activity in building new plants in the localities above mentioned as well as in Canada and Mexico. The tendency has been towards fewer units and larger units, towards a keener appreciation of the reduction in cost resulting from using a large output as a divisor, particularly with reference to the reduction of the cost of management and fixed charges.

A series of observations by barometer and hygrometer emphasize the disadvantages of high humidity, and have led in a few instances where there were hot, moist engine-rooms to the supply of air from outside the building by means of specially constructed pipes. This also is a line of investigation receiving the attention of some of our foremost furnace managers.

I fully realize that many names entitled to special mention for having taken a prominent part in the astounding progress of our industry have been omitted from this paper, and I can only trust that no one will feel that a discourtesy has been intended. I cannot, however, close this brief record without the mention of the one whom I think has most clearly discerned the trend of events. Mr. James Gayley early saw the possibilities of Mesabi ores and the methods of handling them, as he also saw the advantages of a low bosh and a large hearth. Both in justice and with a sense of personal loyalty, I feel that the name of Mr. James Gayley should be placed permanently among those who have contributed so much to the splendid development of the blast-furnace practice during recent years.

MACHINE-MIXED CONCRETE AS APPLIED TO STREET WORK.

By D. G. Fisher.*

The accompanying cuts, Figs. 1 to 3, show a method of mixing and handling concrete that may be of interest to engineers and contractors who have a considerable concrete yardage to lay in a comparatively small district where a centrally-located plant can be installed.

The advantages of such an arrangement over the ordinary methods are as follows:

(a) Decreased cost per unit, account of reduction in number of times material is handled.

(b) No labor troubles, account of the comparatively small number of men employed.

(c) No waste of materials, especially of cement, account of wet weather and broken or torn sacks.

(d) A better and more uniform mixture and an absolute certainty as to the proportion of materials and amount of water used.

The plant as shown was a complete success, both from a financial and an engineering point of view, and was devised because it was necessary to complete a large yardage in a short space of time, during a rainy season, where labor and teams were poor, high-priced, and hard to obtain.

The method of operation was as follows:

Fig. 1 illustrates the general arrangement showing cement shed, engine, storage bin and charging platform.

Fig. 2 shows the elevators and the teams with dump wagons for receiving and delivering the mixed concrete to street, where it is spread and tamped in place by a small gang of men.

Fig. 3 shows the two one-half yard mixers of double cone and cube type, with the pipes for delivering the water to the machines and the loading car.

The gravel is dumped into a large hopper at the base of the elevator and carried to the bin. If sand and stone are used, two hoppers, two elevators, and two compartments in the bin are required for a careful proportioning of quantities. A gate in the bottom of the bin allows the material to pass to receiving hoppers on the charging platform, where the cement is added. At a given signal, when the mixer has dumped and returned to position, a second gate is opened, admitting the charge to the machine, where it is thoroughly mixed dry. The water is then added and the batch dumped into a loading car or directly into a wagon. Our longest haul was about 30 mins., and very careful tests, both at the end of a few days and at the end of two months, showed the concrete to have good set and bond, and in my opinion, superior to what would have been obtained from the ordinary method of hand mixing.

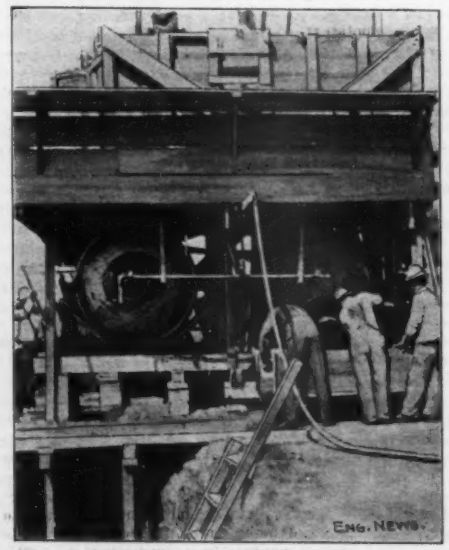


Fig. 3. A Double-Cone and a Cube Mixer Working Side by Side.

With labor at $1.75 and teams at $4 for 10 hours, and engine at $5 a day, concrete may be mixed and put in place for 30 to 40 cts. per cu. yd., the cost varying with the management.

Mr. Umstead, in concluding a paper printed in Engineering News, Jan. 14, 1904, invites discussion on methods that have been employed for laying concrete in freezing weather. I have obtained entirely satisfactory concrete in zero weather by simply using hot water. Pedestals for crane runways and retaining walls put in place by this method, at the end of three years are perfectly intact.

*Asst. Eng. The Laclede Gas Light Co., St. Louis, Mo.

A NEW JOINTING MATERIAL—SULPHUR AND SAND—FOR SEWER PIPES.

By Alexander Potter,* C. E.

The difficulties connected with the use of cement for joints on pipe sewer construction are well known. The objectionable features of cement for this service are numerous: leakage, admission of tree roots, the seasonal restrictions of its use on account of frost. These objections are not even eliminated when the work is under the supervision of competent engineers. As an instance of this, Prof. A. P. Folwell, in an address before the American Society of Municipal Improvements, records the fact that in a city in New York State the ground water infiltration in the pipe sewers was only limited by the capacity of the sewers. While the name of the city was withheld, I believe it to be a city where the designing and supervising engineer, and also the resident engineer, are all members of the American Society of Civil Engineers, and are men who stand well in the profession.

Many other cases of leaky sewers have been cited from time to time, and most other sewers could come under the same category if they were subjected to ground water infiltration. It is axiomatic that it is impossible to make a joint even approximately water-tight with the use of cement applied in the customary manner.

The writer has devoted much of his time to attempting to secure water-tight work, and has used cement in various ways and in combination with tar and other materials, with indifferent success, notwithstanding highly satisfactory laboratory results.

The method now in use upon his work secures as nearly water-tight joints as can be devised. In the construction of pipe sewers under his charge, the writer has largely dispensed with the use of cement as a jointing medium and has substituted therefor a mixture of sulphur and sand in the proportion of 1 to 1, approximately, heated together at a temperature of 230° F., and used in a similar manner to jointing water pipe.

The physical and chemical tests of the mixture show it to be superior in all important respects to Portland cement mortar, both neat and mixed with sand. The tests show that while the tensile strength of pure sulphur is about 100 lbs. per sq. in., the sulphur and sand composition has a tensile strength of 400 to 700 lbs. per sq. in., depending on the quantity of sand used. Several briquettes tested two hours after they were poured broke at 670 lbs. per sq. in. The average of one-day and 5-day tests of pure sulphur briquettes gave 100 lbs. per sq. in., while for the same time a 2 of sulphur to 1 of sand mixture gave 400 lbs. per sq. in., a 1 to 1 about 650 lbs., and a 5 to 7 about 670 lbs. After cooling, time does not seem to be an element in affecting the strength of the mixture.

The writer submitted samples of the mixtures to Ledoux & Co., chemists, who report that under 72-

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hour test the composition was not affected by any of the acids or alkaline liquors to which samples of the mixture were submitted, when present in such quantities as are likely to be found in sewage. A 5% solution was used for the tests. The tests made by the chemist further show that the mixture is practically impervious to water, the absorption averaging .017 of one per cent. The material melts quite sharply at 230° F. without any apparent preliminary softening. This is the same as sulphur, and means that until the sewer should be subjected to 230° F., the joints could in no way be affected.

The tests conducted by the writer to determine the tensile strength developed the interesting fact that the more sand the sulphur could take up and yet run freely, the stronger the resultant mixture. It also shows that the finer the sand the more satisfactory the resultant. The coarser sand precipitates more rapidly. The sand now being used has an effective size of 0.135 millimeters and a uniformity coefficient of 2.5. All sand passed a No. 40 sieve, and 30% of it was held on a No. 60 sieve. This is a very fine sand, the ordinary New Jersey quicksand. Experiments were made with the use of fine Long Island beach sand, but the results obtained were less satisfactory than with quicksand. At last a use has been discovered for quicksand!

The amount of the compound used is less than one-half the quantity of cement mortar required for making joints, and the labor of making the joints is less than required in making a cement joint *as it ought to be made.*

This new form of joint has a further important advantage in construction, that water can be allowed to rise in the ditch and run through the pipe one minute after the joint has been made. It is also proof against the intrusion of roots into the sewer.

The universal application of this mixture as a jointing material for sewer work would unquestionably tend to increase to a slight extent the cost of sewer construction, because the enforcement of specifications concerning cement joints on sewer pipes are more honored in the breach than in the observance, and the prices of the contractors are figured on this basis. But, as has been said, if any reasonable effort is made to secure tight sewers with cement joints, the cost of joints with sulphur and sand will be no greater than with the cement.

In laying the sewer in wet trenches, the ditch is excavated 6 ins. below the bottom of the pipe, which is blocked up to grade. The water is thus more readily kept away from the bells. A heavy gasket of oakum, about 0.6 lb. for a 24-in. pipe, is thoroughly calked into the joint. Any ordinary form of pipe jointer used in water pipe laying is fastened around the pipe and the joint poured as in laying water pipe. It is advisable to have several pipe jointers in use so that a section of 9 ft. can be jointed while the water is being temporarily held down below the bottom of the sewer in a wet trench. Material for three or more joints can be heated more economically than for one joint.

For the smaller pipe, that is to say for 8-in., 10-in., and 12-in., cradles can be set up on the bank and three or four lengths of pipe can be readily jointed together. In ten minutes after the joints are poured they can be removed from the cradles and lowered into the ditch as one pipe.

The rigidity of the joints makes it almost essential to deposit concrete under the haunches of the large pipe and on 24 and 22-in. pipe sewer 2.3 cu ft. of concrete per ft. of sewer is found sufficient to give the pipe a proper bearing. A lean, natural cement concrete gives satisfactory results and the cost will depend upon the acessibility of materials. Where it is possible to lay pipe simply by digging out bell holes, the concrete can be dispensed with; but in the opinion of the writer, concrete is essential under all large sewers in wet trenches and in rock cuts, when an attempt is made to secure perfect joints with cement or otherwise, for then a rigid beam has been produced, which, without a continuous foundation, is liable to rupture.

Tests were made with various kinds of sulphur; the crude Sicilian (1.5 cts, per lb.); the roll sulphur (2 cts, per lb.), and the flour sulphur (2.4 cts, per lb.). The latter, while most expensive, is most satisfactory and melts much more rapidly than the crude or roll sulphur. The labor element of cost is thus reduced sufficiently to offset the difference in cost of material.

The mixture can be prepared in a number of ways.

An oil or gasoline furnace gives a more uniform heat than other methods of heating, and is the most satisfactory. The most serviceable size of pot is one that will hold enough material at one time for at least three joints on the larger pipe to a dozen joints on the small pipe. The specific gravity of the melted mixture is 2.46.

The following table gives information concerning the cost and amount of material in making sulphur-sand joints.

Approximate Costs.

Size of pipe.	Amt. of mixture, lbs. per joint.	Mixture.	Gasket.	Fuel.	Labor.	Total.	Per foot lengths 3-ft.	Per foot lengths 2-ft.
24-in.	10.0	.125	.02	.02	.13	.295	.10	.15
22-in.	9.0	.1125	.02	.02	.13	.282	.095	.14
20-in.	8.0	.10	.02	.02	.12	.260	.09	.13
18-in.	7.0	.087	.02	.02	.11	.247	.08	.12
15-in.	5.5	.069	.01	.01	.10	.187	.063	.095
12-in.	4.2	.052	.01	.01	.09	.162	.055	.08
10-in.	3.3	.041	.01	.01	.08	.141	.045	.07
8-in.	2.5	.031	.01	.01	.07	.121	.04	.06

The exclusion of ground water will increase the capacity of the sewer from 10% to 100% through territory subject to the admission of ground water, so that the increase in cost becomes a trifling matter, especially when it is considered that tree roots are kept out of the sewer.

NOTES ON RAIL-STEEL.*

By Robert W. Hunt,† M. Am. Inst. M. E.

I have repeatedly stated that the mechanical treatment of the metal forming a steel rail, during its manufacture, was comperatively of much greater importance than its chemical composition. Years of observation have confirmed and emphasized that fact.

The comparison of the wear of the earlier steel rails with that of later ones, and to the great disadvantage of the latter, is still being constantly made by railway officials. And while some of us, with experience covering the whole history of the manufacture of steel rails, are aware of the great differences in the conditions governing their production at various periods, I do not think the engineering world generally appreciates the direct and imperative influence those variations have had, and are having, upon the wearing quality of the rails.

In the earlier days the steel was poured into ingots which would make but two 30-ft. rails of not exceeding 60 lbs. weight per yd.—giving a mass weighing, say about 1,400 lbs., and of a section of about 12 ins. square. To-day the ingots are some 22 ins. square, and weigh more than 4,000 lbs. Of course, the interior of the larger ingots must remain hot and liquid longer than that of the smaller ones, and from this condition arises the steel rail maker's bete noir—segregation of the metalloids and piping of the steel. The smallest sectioned ingot will pipe, but with the increase of its size, so will be that of the interior cavity. This tendency existing and being well known, it would seem that rather than being ignored, especial care should be exercised to avoid the evils arising from it.

In the earlier days of steel-rail making, after the ingot had been rolled down to a bloom of 6 or 7 ins. square, all cracks were carefully chipped out of it. Such defects could not be welded up by subsequent working, but if cut out to the deepest point, particularly if the forming of sharp corners was avoided, the steel would, when further rolled, draw from the bottom up; and so if the cavity was not too deep, a sound bar or rail would result. This chipping was performed under a steam hammer. Later, if while the bar was passing between the rolls of the rail mill defects were discovered, the rolling operation was suspended until they could be chipped out. Then, again, great care was taken that the steel bloom should not be overheated. There were from six to eight blooms, each of a size to produce one rail, charged at one time into a heating furnace; and skilled workmen attended to their heating, turning them over on the bottom of the furnace so that all sides should become of an equal temperature. If from any cause this man made a mistake, and sent his steel to the rolls in an unsatisfactorily heated condition, the head rail roller, or some other mill official, rejected it, and it was returned to him for further treatment. This meant that more or less care was exercised on each and every rail; but the daily production was, when viewed from to-day's standpoint, quite small. The first departure was to cease chipping the blooms at the rail rolls—the next, to make it one continuous process from the first blooming of the ingot to the finished rolling of the rails. This procedure stopped the intermediate chipping of the blooms under the steam hammer, and carried with it the rolling of more than one length rail, that is, the rolling of a mass of steel large enough to produce more than one rail length, and the subsequent sawing of this into two or more rails.

This new method of rolling had been made possible by the introduction of more or less automatic machinery, and the daily production of a given rail mill increased rapidly. But, I regret to say, that the care which was possible to bestow on the making of each individual rail decreased in an even greater ratio—an effect which was inevitable.

In the old days, a Bessemer converting house was equipped with two converters, each of about 5 tons capacity, which were gradually enlarged to 7, 10, 15 and on to 20 tons, and additional converters added. Of course the size of the house, blowing engines, cranes, etc., were all proportionately increased, and the development of the plant has proceeded until, instead of about 12,000 tons of ingots per month coming out of one converting house, more than 70,000 tons per month are now produced. There is more and larger machinery, and it has been said such large product is the best evidence that everything must have been running smoothly. That is true so far as mere production goes, but the speed and momentum are against the exercise of the proper kind of care necessary to produce sound ingots of the highest quality of steel. This is old-fashioned doctrine, but it is true. What are we going to do about it? I am not at all certain that I know; but I do think that the condition should not be tacitly accepted, and no effort made toward better things.

Of course, if the same radical course should be pursued with rail ingots as is done with those intended for ordnance, armor or heavy shafting purposes, by which the upper portion of each ingot, amounting to quite one-fourth of its entire weight, is cut off and treated as scrap, we know the greatest danger from segregation and piping would be eliminated. But this procedure will reduce the output of finished rails, and in that and other ways add much to the cost of making them. But if it is necessary in order to obtain safe rails, should not the situation be boldly faced? If railways must pay more money, and can by so doing secure rails which will not only be safe against breakage under traffic, but also give better wear, will it not be economy for them to make the greater investment? That would be one way to meet the difficulty, but I believe there are others also.

Alexander L. Holley had more to do with the introduction in America of the Bessemer process for making steel than any other man; and, later, probably did more than any one else to make possible its greatly increased and cheapened output. Some years after that process was firmly established in this country, the Siemens-Martin or open-hearth process was developed and Mr. Holley was convinced that it also had a great future in America. So outspoken was he in support of this, that on one occasion an intimate associate of his, and one of the "Bessemer Family of Boys," said to him: "It sounds strange for you, of all men, to advocate so strongly the merits of the open-hearth process." He replied: "You mark my words, the open-hearth process will live to attend the funeral of the Bessemer process in America."

There are a number of the "Boys" still alive, and great changes along the line of Holley's prophetic vision have occurred; so that to them its fulfilment does not seem as improbable as when it was made.

In my judgment, the one question of ore supply will, in time, compel the increased use in this country of the basic open-hearth process. We cannot forever continue the rejection of ores which are in every other quality suitable for steel making, because their phosphorus content is outside of the Bessemer limit. And if at the same time, by the use of the other process, we produce a better metal, at cost not much if any greater, the outcome is inevitable.

Phosphorus is the controlling element in rail steel. If that can be practically disregarded, no one will deny the ability to make a better article, no matter for what purpose it may be intended.

So far as rails are concerned, the theory relating to the difference in the wear of the steel made by the two processes is being subjected to the crucial test of practice. But no matter what steel is used, care must be exercised in making it; in pouring the ingots; in their handling and heating, and in the rolling and straightening of the rails.

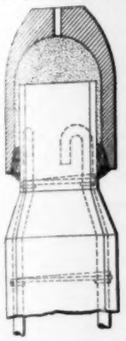
While I have at different times prepared and presented to this Institute specifications for the manufacture of rails, I feel that under all the existing conditions the present is not the time for the adoption of any specification as standard. For the last few years, commercial conditions have been such that there has been practically but one side to the market. Such is not now exactly the case. The rails of heavy sections have not been giving the anticipated service. Both Bessemer and basic open-hearth rails are being made in America, and placed in service, side by side. Foreign rails of both basic and acid Bessemer steel have been imported. Several of the large railway systems have contracted for rails under somewhat new specifications. Let us, before saying which or any are the best, await results of actual experience. But I repeat, no matter what chemical formula, or which process of making steel, is selected, unless care in manufacture is exercised, all will have been in vain.

*A paper read at the Atlantic City meeting of the American Institute of Mining Engineers.

†Consulting Engineer, 1121 The Rookery, Chicago, Ill.

THE CONSTRUCTION AND USE OF CONCRETE STEEL PILES IN FOUNDATION WORK.*

CONCRETE-STEEL PILE FOUNDATIONS.—The construction of foundations with concrete-steel piles does not differ materially from the familiar construction of timber pile foundations; the piles are driven in rows or in clusters and capped with a platform or grillage of concrete or concrete-steel, on which the masonry or steel superstructure is built in the usual manner. In construction concrete-steel piles are not essentially different from columns of that material; they may be employed for the same purposes and in much the same manner as timber piles. Compared with timber piles, they have several advantages and some disadvantages. Their most important advantage, perhaps, is that they are equally durable in dry or wet soil, while piles of timber must be constantly submerged to remain preserved. Their most serious disadvantages are that they are more expensive in first cost and more troublesome to drive than timber piles. In recent practice, however, the difficulty of driving concrete-steel piles has been largely overcome, and with care it is probable that such piles can be driven in almost any soil that timber piles will penetrate. Pile for pile, concrete will usually cost more than timber. Often, however, its use will effect a saving in the total cost of the foundation, since, not having to cut the piles off below ground water level, the depth of excavation and volume of masonry may be reduced. Another advantage of concrete-steel piles is the readiness and efficiency with which they may be bonded monolithically with the grillage or capping of concrete or reinforced concrete which embeds their tops. In a word, concrete-steel piles promise to combine the advantages of timber piles with some of the advantages of masonry piers, and in particular their independence of moisture conditions and their freedom from the ravages of the teredo make them particularly suitable for marine work.



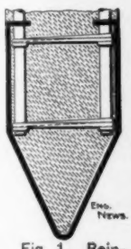


Fig. 1. Reinforced Concrete Pile of Hennebique Construction.

CAST-PILE CONSTRUCTION.—The illustrations of Figs. 1 to 18 show the principal forms of concrete-steel piles which have been employed in construction. The writer knows of no instance of a cast reinforced concrete pile of circular section being used. Such a form of pile would possess certain obvious advantages over rectilinear sections, but it would be more expensive because of the greater complexity of the molds and of the reinforcement required in its construction. All the piles illustrated are rectilinear in cross-section, and all but one are quadrilateral.

Fig. 1 shows the form of bearing pile designed and used in a number of important structures by the French engineer Hennebique. It is square in section, the point being pyramidal and the top being shouldered in with a round section above the shoulder to permit the application of a driving cap. The point is shod with a cast-iron shoe, consisting of a point and four side straps, which bend in at their tops to lock into the concrete. The reinforcement consists of four round soft iron rods placed at the four corners and wired together at intervals as shown by the drawing. In some instances this reinforcement is increased by four additional rods placed midway of the sides. The piles are also sometimes constructed with a circular hole running lengthwise of them at the center. This hole bifurcates into two reaching to the beveled surfaces at the point and serves for a water jet during driving and as a means of forcing grout into the soil surrounding the point when the pile has penetrated to its final position. It is filled previous to capping the pile. In the construction of sheet piles, Mr. Hennebique changes the cross-section from a square to a rectangular slab and employs six instead of four reinforcing bars, the two additional bars being placed one midway of each broad face of the pile. The point is formed by beveling one of the narrow faces so as to form a wedge edge with the opposite face, and both narrow faces are slotted by a semicircular groove running from point to shoulder. These semicircular grooves form, when the piles are driven as sheeting, a circular hole from top to bottom between each pair of piles. This hole serves for a water jet during driving, and afterwards for injecting grout into the soil around the points. The final filling of the circular hole forms a monolithic plate of the sheeting. The cross-section, Fig. 2, shows the form of sheet pile whose construction has been described. Another concrete-steel sheet pile of European design is shown by Fig. 3. The reinforcement consists of two parallel I-beams tied together at intervals of about 7.7 ft. by means of plate and angle cross ties. One of the narrow faces is grooved, and the other has a tongue to provide for the interlocking of the adjacent piles when they are driven as sheeting. The particular pile illustrated was employed for a quay wall, and the anchor rod shown at the top was carried back into the filling of the quay and fastened to a massive concrete anchor.

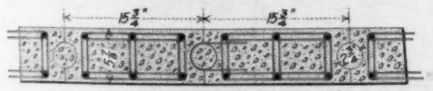


Fig. 2. Transverse Section of Reinforced Concrete Sheet Piling, Hennebique Construction.

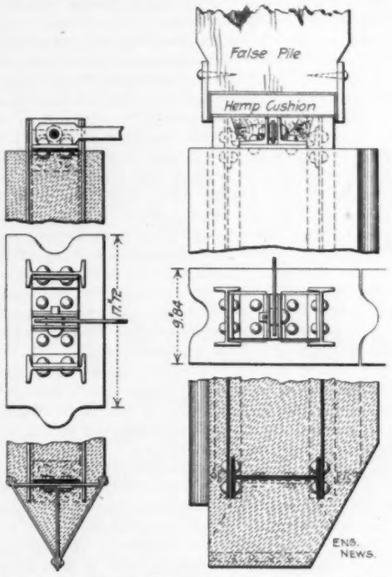


Fig. 3. Reinforced Concrete Sheet Pile with I-Beam Skeleton.

Fig. 4 shows a form of concrete-steel pile which was employed in the foundation construction for a court house built near Berlin, Germany. As will be seen, the pile is triangular in section, with the apices of the triangle cut off, and is reinforced by three 1-in. iron rods placed at the corners and wired together at intervals of 8 ins. by ties of ¼-in. wire. At the bottom of the pile the ends of the three rods converge to a point and are welded together. The concrete mixture was 1 part Portland cement and 3 parts river gravel. A reinforced concrete pile of American design is shown by Fig. 5, and the design is notable both because of the importance of the foundation in which it is used and because it avoids all patented features. The pile is square in cross-section, with a pyramidal point and flat top, and is made of 1-2-4 Portland cement concrete. The reinforcement consists of four 1-7/16-in. rods placed at the corners and extending down into the pyramidal point, where they take seat on the cast-iron shoe point. This point is anchored to the pile by wrought-iron straps bent in at their tops. Throughout the shaft of the pile the reinforcing rods are bound together at intervals by wire ties. At the top of the pile the concrete is carried 2 ins. above the tops of the reinforcing rods, but after the piles are driven this top concrete may be broken off, leaving the rods projecting to bond the pile with its capping.

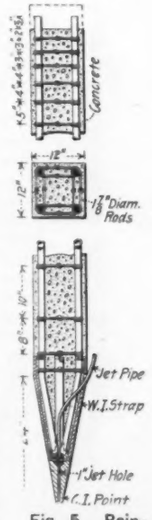


Fig. 5. Reinforced Concrete Pile for Building Foundation at New York City.

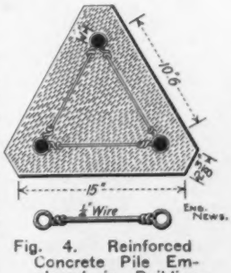


Fig. 4. Reinforced Concrete Pile Employed in Building Foundation at Berlin, Germany.

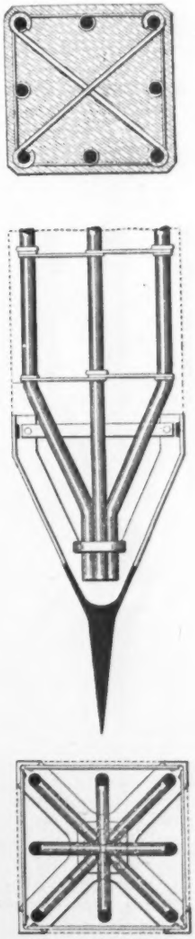


Fig. 6. Reinforced Concrete Pile for Wharf at Novorossisk, Russia.

Fig. 6 shows the form of concrete-steel pile employed in constructing a wharf at Novorossisk, Russia. Altogether 24 of these piles were employed. They were each 15.75 ins. square and were pointed and reinforced as shown by the drawings. The reinforcement weighed about 45 lbs. per lin. ft. of pile, and the total weight of the pile per lineal foot was about 262 lbs. Each pile had to support a section of wharf floor 269 sq. ft. in area, and to carry a load of 85,584 lbs.

CONCRETE-STEEL PILES BUILT IN PLACE.—The forms of reinforced concrete piles so far described are molded complete, and after hardening are driven like timber piles. A number of inventors have recently devised methods of constructing the piles in place, and these are fully described in the succeeding section. Two forms of reinforced concrete piles which are designed to be constructed in place are described in the following paragraphs. So far as the author knows, these forms of concrete-steel piles have never been used in actual construction, but plain concrete piles of the same form and constructed in the same manner, excepting that the reinforcement was not inserted, have been employed in a number of important structures. Fig. 7 shows transverse horizontal and vertical longitudinal sections of the reinforced concrete pile designed by the engineers

*Extract from a forthcoming book on Reinforced Concrete Construction by A. W. Buel and Chas. S. Hill.

of the Simplex Concrete Piling Co., of Philadelphia, Pa. This pile is reinforced by a circumferential cylinder of expanded metal. The reinforcing metal has a thickness of 5-16-in. and a 3-in. mesh. Fig. 8 shows the concrete-steel pile made by the Raymond Concrete Pile Co., of Chicago, Ill.

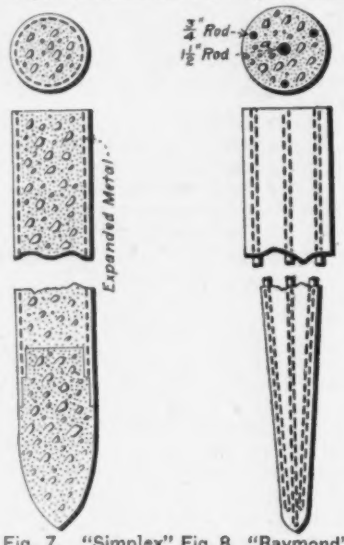
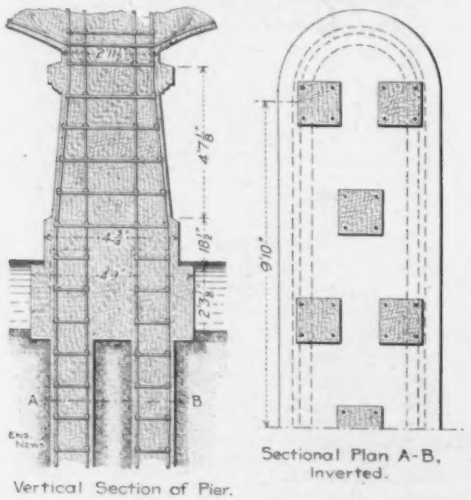


Fig. 7. "Simplex" Pile of Reinforced Concrete Built in Place.

Fig. 8. "Raymond" Pile of Reinforced Concrete Built in Place.

The reinforcement consists of a round bar about 1½ ins. in diameter, extending lengthwise of the pile along its axis, and of three similar bars spaced equidistant around the circumference. These outside bars are generally ¾-in. in diameter. The pile is usually made with a uniform taper from butt to point.

EXAMPLES OF FOUNDATIONS. — Fig. 9 shows the reinforced concrete pile foundation and pier of the Brumath Bridge in Alsace-Lorraine. The piles, pier and spans are all of Hennebique construction. As will be seen, the pier rests on eleven piles, which are in one piece with it, this monolithic construction being obtained by practically continuing the reinforcing rods up through the pier. The piles used were 14 and 16 ft. long and 16 ins. square, and the foundation bed consisted of about 6½ ft. of swamp mud overlying coarse gravel. With an 8,800-lb. hammer and a drop of 20 ins., the piles penetrated the soft material from 8 to 12 ins. at each blow; in the gravel with a drop of hammer of 2⅓ to 4¼ ft. the penetration was 2 ins. at first, and gradually decreased to 0.4-in. The ultimate bearing power of these piles was figured by Ritter's formula.



Vertical Section of Pier. Sectional Plan A-B, Inverted.

Fig. 9. Reinforced Concrete Pile Foundation for Brumath Bridge Piers, Alsace-Lorraine.

$$W = \frac{h}{e} \cdot \frac{Q^2}{Q+q} + Q + q,$$

to be 546,000 lbs. each, the values taken being

Q = Weight of hammer in pounds = 8,800,
q = Weight of pile in pounds = 8,800,
H = Height of fall in inches = 48,
E = Final penetration in inches = 0.4.

This foundation, though small, shows the unity of structure which is readily obtained when reinforced concrete piles are combined with a capping or superstructure of the same material. A concrete-steel foundation of more pretentious character is shown by the drawings of Figs. 10 and 11. This foundation was employed for a ten-story addition to the Hallenbeck Building in New York city. Fig. 10 is a general plan and sections of the foundation, and illustrates its arrangement and character quite plainly. The piles were of the construction shown by Fig. 5. The piles of each group of two, four or six piles were capped with a reinforced concrete slab constructed as shown by Fig. 11. The piles were calculated to sustain 80,000 lbs. each, made up of 36,000 lbs. per square foot allowed by the New York Building Laws for concrete piers and an additional load of 44,000 lbs. borne by the four reinforcing rods.

Fig. 12 is a diagram cross-section of a quay wall somewhat over 400 ft. long, which was built for the London & Southwestern Ry., at Southampton, England, in 1898. Longitudinally of the wall the supporting piles were spaced 3 ft. 7 ins. apart, and those of the front row under the face of the wall were filled between with concrete-steel sheet piles. Both bearing and sheet piles were of Hennebique construction. The bearing piles were 12 × 12 ins. in section and were reinforced by eight 1⅛-in. bars connected by 3-16-in. ties. A wharf carried by concrete-steel piles and constructed at Southampton, England, in 1898, is shown in cross-section and part longitudinal section by Fig. 13. This wharf consists of two parts at right angles to each other; one part is 90 ft. long and 30 ft. wide, and the other part is 100 ft. long and 46 ft. wide. The foundation piles are 12 ins. square and are reinforced with four rods; they carry a superstructure of columns and platform of concrete-steel. The pier is designed for a load of about 575 lbs. per square foot.

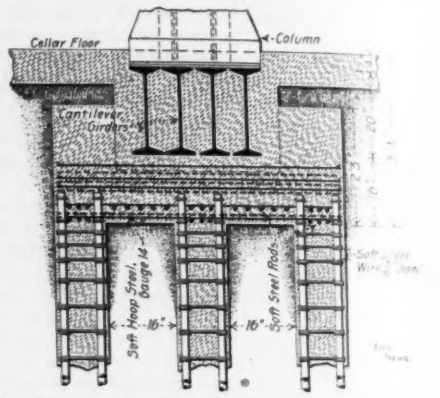
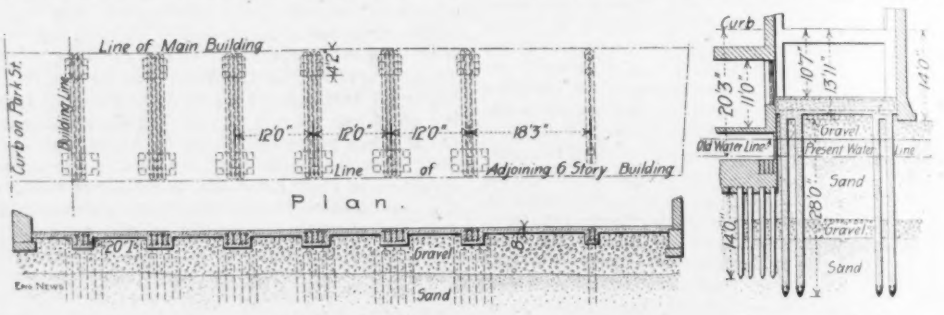


Fig. 11. Section Showing Reinforcement of Piles and Pile Capping for Hallenbeck Building Foundations.



Longitudinal Section. Transverse Section.

FIG. 10. REINFORCED CONCRETE PILE FOUNDATION FOR HALLENBECK BUILDING. NEW YORK CITY.

CASTING CONCRETE-STEEL PILES.—The casting of reinforced concrete piles is analogous in all respects to the molding of columns or beams in place; when the mold is set upright the molding of piles resembles that of columns, and when the mold is set horizontally the molding resembles that of beams. Each method possesses advantages and disadvantages. In vertical molding there is the advantage of having the layers in which the concrete is tamped at right angles to the line of pressure on the pile, and the disadvantage of having to compact the concrete in a narrow space with long rammers. In horizontal molding the planes of the layers are parallel to the direction of the pressure, but the molding is performed under much easier conditions. These factors are of more significance in Europe where a dry concrete is used than they would be where wet mixtures are employed as is common in American practice. The forms for molding piles are similar to the forms employed for constructing columns and beams. As they have to be used over and over they should be so constructed that they can be rapidly assembled and taken apart. The piles can be removed from the forms in one or two days, but they are not sufficiently hardened to be driven for about 30 days.

The following is the method in detail which was adopted in constructing the triangular piles illustrated by Fig. 4. The molds or forms were set up vertically and the concrete placed in them in 8-in. layers. The concrete was mixed very carefully in machine mixers and was made with a minimum amount of water. Of the three sides of the mold, two sides were set up to the full height, but the third side was built up as the concrete was placed. The reinforcing rods were placed and secured in position before any concrete was placed. Each 8-in. layer of concrete was rammed down as hard as could be done with hand rammers, then the top surface was roughened with a trowel and a set of spacing ties placed on the rods. Another 8-in. layer was then placed. Piles were built in this way to lengths varying from 16 to 26 ft. After being molded the pile was left to set for about a day, without water, and was then kept in the form for about a week longer with continual sprinkling. By that time the piles had hardened sufficiently to allow them to be lifted vertically out of the forms and set away in a vertical position for another period of a week or so, during which time they were kept constantly wet. After this they could be removed for transportation or storage.

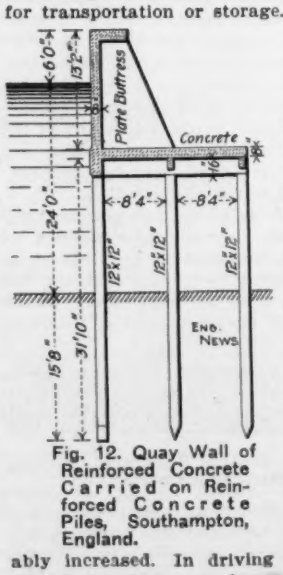
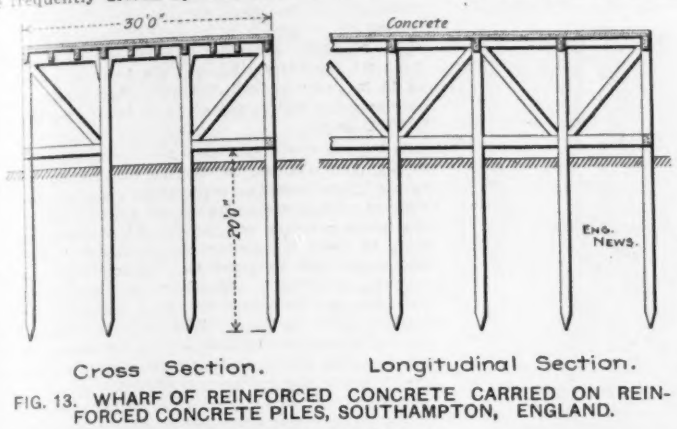


Fig. 12. Quay Wall of Reinforced Concrete Carried on Reinforced Concrete Piles, Southampton, England.

DRIVING CONCRETE-STEEL PILES.—Reinforced concrete piles may be driven by hammer pile drivers or by water jet or in any other manner in which timber piles are driven. In driving by hammer, however, the fall of the hammer is usually decreased and some form of driving cap designed to distribute the impact stress evenly over the top of the pile is usually employed. The weight of the hammer, on the other hand, is usually considerably increased. In driving the triangular piles described above a hammer weighing 5,000 lbs., with a drop of 5 ft., was employed. The 16-in. square piles of Hennebique construction employed for the Brumath Bridge.

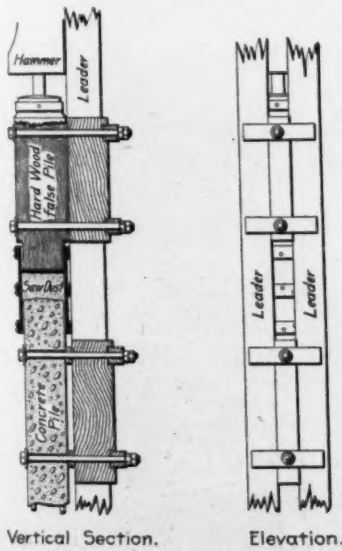
and illustrated by Fig. 9, were driven with an 8,800-lb. hammer with a maximum drop of 8 ft., which was decreased as the penetration decreased. Mr. Charles F. Marsh is authority* for the statement that Hennebique piles 12 ins. square are frequently driven by a 30-cwt. hammer with a drop of 4 ft. In driving sheet piling 0.3 × 0.4-m. (11.8 × 14.8 ins.) in cross-section at Chantenay sur Loire in 1898 a hammer weighing 3,520 lbs. and having a drop of 6.25 ft. was employed. In constructing the wharf at Novorossisk, Russia, the pile illustrated by Fig. 6, was driven 2 ft. into hard bottom with from 10 to 14 blows of a 3,375-lb. hammer falling from 12 ft. to 14 ft. Except that stronger tackle is required to handle the heavier concrete-steel pile, the ordinary pile driving rig for timber piles is all that is essential.



Cross Section. Longitudinal Section.

FIG. 13. WHARF OF REINFORCED CONCRETE CARRIED ON REINFORCED CONCRETE PILES, SOUTHAMPTON, ENGLAND.

To protect the heads of concrete-steel piles during driving use is made of a cap or false pile, to distribute the shock. The most carefully worked out device of this kind is the cast steel cap devised and used by Mr. Hennebique. This cap is shown by Fig. 1. It is a cup-shaped casting which fits over the neck of the pile loosely. The annular opening at its lower edge is caulked with clay and tow and the hollow space above is filled through a hole in the top of the cap with sand, or, preferably, with sawdust. A separate cap is required for each size of pile. In driving a large lot of Hennebique sheet piling at Southampton, England, a false pile was used in addition to the metal cap. A rather more complicated arrangement, which was employed in driving sheet piling at Chantenay Sur Loire, France, is shown by Fig. 14. Here the piles were cast with unreinforced tops, which were designed to be broken off enough after driving to expose the reinforcement for bonding to the work above. This allowed the top of the pile to be clamped loosely to the guides of the pile driver as shown. A metal cap with an upper and lower socket was set on the neck of the pile, with a filling of sawdust over the pile top, and its upper socket received the end of a hard wood false pile clamped to the pile driver guides as shown. The relative positions of the pile, its cap and the false pile and hammer are clearly shown by the illustration. In driving the triangular piles shown by Fig. 4, a cap was used which was made of alternate layers of iron plate, wood and lead. This cap was clamped to the pile head and also served to guide the pile in the leads. Another device used consists of a metal cap like that shown by Fig. 1, but having a socket on top in which is set a disk of hard wood to take the direct blow of the hammer.



Vertical Section. Elevation.

Fig. 14. False Pile and Cushion Cap For Driving Reinforced Concrete Piles at Chantenay Sur Loire.

Where the nature of the soil permits a water jet is always a safe and sure method of driving concrete-steel piles. Piles designed for this method of driving are cast with a hollow center or have jet pipes cast into the concrete, as shown by several of the preceding illustrations. The method of driving and the apparatus employed are the same as are used in timber pile work.

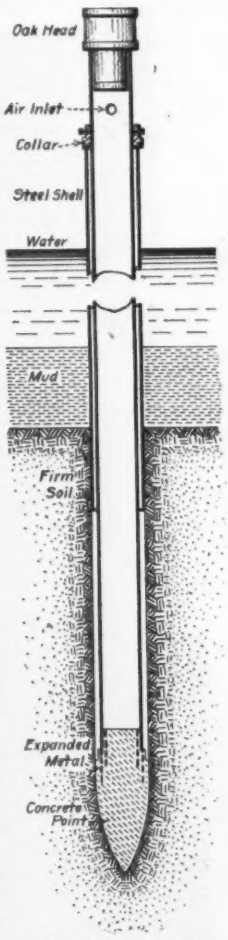


Fig. 15. "Simplex" Driving Shell for Molding Reinforced Concrete Piles in Place.

CONSTRUCTING PILES IN PLACE.—In the preceding section two forms of reinforced concrete piles designed to be constructed in place are described. To perform this task use is made in both cases of a pointed metal cylinder or casing for forming the hole to be occupied by the pile and for retaining the walls of this hole in place until the concrete is placed. Fig. 15 shows the arrangement adopted for the so-called Simplex pile construction. A wrought iron cylinder of the diameter and length which the pile is required to be, is slipped over the neck of a previously cast concrete point. This cylinder, with its point, is driven by means of an ordinary pile driver to the depth required, there being an oak driving cap or head, applied to the cylinder to receive the blow of the hammer. When completely driven, the cylinder of expanded metal reinforcement is slipped inside the driving cylinder until its lower end bears on the concrete point. Concrete is then shoveled into the driving cylinder, which is gradually withdrawn as the filling progresses, until it is entirely free. Another concrete point is then attached and a second pile completed. Only the single driving cylinder is employed when the pile penetrates earth throughout, but when there is a depth of water overlying the earth as is the case in driving piles in a stream or lake bottom, a second cylinder or shell is clamped outside the driving cylinder, as shown in the illustration. This shell is shorter than the driving cylinder, and, in fact, is just long enough to penetrate the bottom a sufficient distance to prevent the free access of water to the hole. It is driven with the driving cylinder, which is withdrawn, leaving it in place by simply unclamping the collar. This shell forms the metal for that portion of the pile above the bed of the stream, and is left permanently in place.

The Simplex pile was used in constructing the extensive foundations for the new Engineer School at Washington Barracks, District of Columbia, and a rather careful study of its action was made by the Army Engineers in charge, Capt. J. S. Sewell and Lieut. Clarke S. Smith. From a description furnished by Lieut. Smith, the following data of interest are taken.

The ground where the concrete piles were driven is about 100 ft. back from the river wall along the Potomac. The character of the material penetrated was determined by borings and pits, and proved to be quite variable. The surface of the ground, when work began, was yellow clay mixed with loam. From four to five feet below this is a stratum of blue silt or clay moderately well dried out and compacted. The thickness of this stratum is variable, and in some places is 5 or 6 ft. It is underlaid by wet sand and gravel. The blue silt or clay was no doubt formed by deposit from the river, since a half century ago the shore line extended about 150 ft. further inland.

The reference of the tops of the piles at different places varies between 11 and 14 ft. above mean low water, and the change in the surface of the river due to tides is between 4 and 5 ft. and due to freshets, reaches 11 or 12 ft. From tests it was determined that the upper yellow clay would not stand 500 lbs. pressure per sq. ft. without serious settlement. This small bearing power was caused by the soft layer of blue silt or clay. As the ground is alternately wet and dry, wooden piles could not be used.

For concrete piles the apparatus consisted of a wrought iron shell, an interior driving form, a concrete point, a pile driver and frame and tackle for drawing. The wrought iron shells were made of ⅜-in. thick boiler steel and were 11 ft. long. The same shells were used throughout the work

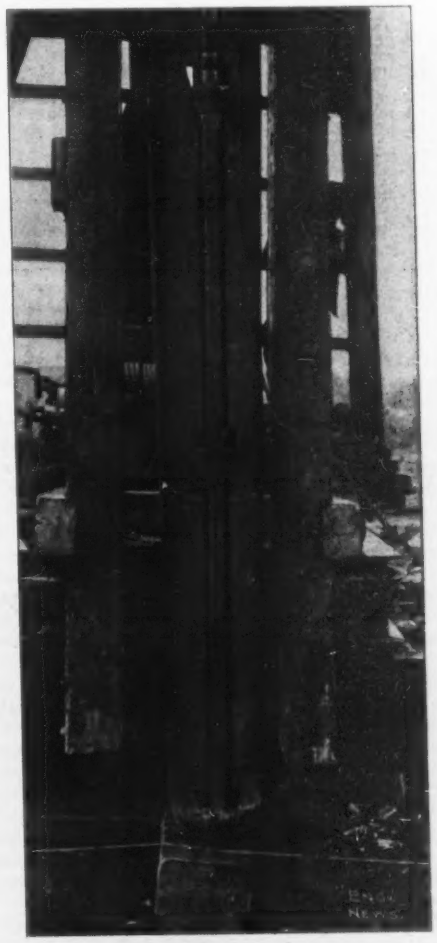


Fig. 16. "Raymond" Driving Shell Core Expanded Ready for Driving.

*Trans. Inst. C. E., Vol. CXLIX.

with occasional repairs to rivets, etc. The interior driving form was a 10-in. cast iron pipe. The lower end of this pipe fitted over the tennon of the concrete point and the upper end held a driving head of black ash, so arranged as to drive both the form and the shell. The shell, form and point, were driven with a 2,200-lb. hammer falling 10 ft., and the penetration at the last few blows averaged ⅛-in., the point of the pile being then embedded in the sand. When the driving form was raised it generally brought up the tennon of the point which had been broken off by the shock of driving. This left a rough top on the point favorable for a good bond between the concrete point and the concrete which was then dropped into the shell.

Enough concrete was placed in the shells at one time to make a layer about 12 ins. thick. Each layer was rammed and the shell was gradually withdrawn so that there was always about 6 in. of concrete in the bottom of the shell. Since the piles were constructed during the wet season, this process prevented the water from entering the shell and kept the earth from caving in. Work progressed during rainy weather almost as well as in good weather.

It was found that the piles could be constructed so that their axes centered well upon the positions staked out. The variation to one side was sometimes 3 or 4 ins. On account of an occasional small boulder, the pile would sometimes glance off to one side and take up a position oblique to the vertical, but this defect could usually be remedied when the shell was being withdrawn. Difficulty was experienced at first in drawing the shell from the ground, but after the apparatus was perfected, there was little trouble.

To determine the bearing value of these piles, one of them was constructed at some distance from the buildings; the concrete was allowed to set two weeks and the pile was then tested and dug up. The result of the test was as follows:

Date.	Lbs.	Change in level reading
April 9, 1903	578	0.000 ft.
" 9, 1903	5,839	0.000 "
" 9, 1903	7,674	0.000 "
" 9, 1903	9,357	0.000 "
" 9, 1903	11,749	0.000 "
" 10, 1903	15,135	0.000 "
" 10, 1903	16,000	0.000 "
" 17, 1903	18,604	0.000 "
" 17, 1903	21,760	0.000 "
" 17, 1903	25,951	0.002 "
" 17, 1903	29,949	0.004 "
" 17, 1903	32,525	0.008 "
" 17, 1903	34,123	0.008 "
" 18, 1903	37,000	0.009 "
" 18, 1903	41,095	0.009 "

The pile, when dug up, showed a uniform cross section and the point was intact, but not very well bonded to the upper part of the pile. However, the pile set squarely on the point and was thus furnished with a good bearing. The length of the pile over all was 13 ft.; the length of the point being 3 ft.

At the site of another building the ground consisted of an upper layer 5 ft. thick of mud pumped in from the river during the last year. Below this is a stratum of soft clay and loam about 3 ft. thick which gradually becomes harder yellow clay as the distance below the surface increases.

There were also some piles constructed 17 ins. in diameter and about 35 ft. long. They penetrated very dry soft blue silt and landed up in sand. The principle was entirely similar to that used for the short pile, but a shell of ⅝-in. thick boiler steel was employed. On account of the great friction on the outside of these shells, they were very difficult to draw until the plan of painting the outside with grease or heavy oil just prior to driving was adopted.

The concrete points were made of one part Vulcanite Portland cement; 2 parts concrete sand and 5 parts broken stone (run of crusher), all by volume. The concrete for the pile was one part Old Dominion Portland cement; 3 parts of concrete sand and 5 parts gravel by volume.

The apparatus employed in constructing Raymond concrete-steel piles is of rather elaborate character. In brief, a core jacketed with a shell of their steel plate is driven into the ground and is then withdrawn leaving the shell in place. Figs. 16 and 17 show the construction of the core. It is made in two longitudinal halves of cast steel between which is fitted a cast steel key, with wedge shaped lugs. When the core is assembled for driving these lugs spread the two halves apart, as shown by Fig. 16, and the three parts are secured by a horizontal key through the head. The steel shell is slipped over the assembled core and the whole is driven by any ordinary pile

Fig. 17. "Raymond" Driving Shell Core Collapsed for Withdrawal from Shell.

driver by means of a driving cap, which sets over the head of the core and has horizontal wings fitting into the guides of the pile-driver. When the driving is completed the horizontal key is taken out and the central key piece of the core is lifted until the lugs slip into the recesses in the side pieces. This position is shown by Fig. 17, and it allows the core to close together or collapse so that it can be easily withdrawn from the shell, the end of which is shown projecting above the ground in Fig. 18.

The reinforcing bars are inserted inside the shell in their proper position, and the remaining space is then filled with concrete. Piles constructed in this manner, but without reinforcement, have been employed successfully in a number of structures. In constructing a library building at Aurora, Ills., 142 piles 20 ins. in diameter at the top and 13 ins. in diameter at the bottom, were driven by an ordinary pile-driver with a 2,400-lb. hammer having a drop of from 20 to 25 ft. The penetration at each blow ranged from ¼-in. to 2 ins. The shell used was made of No. 20 sheet-iron, and the concrete was 1 part Portland cement, 2 parts sand and 4 parts broken stones. The material penetrated was filled ground overlying rock at a depth of 14 ft. The heads of the piles were enclosed in concrete foundation walls, as shown by Fig. 18.

GRAIN PRESSURES IN DEEP BINS.*

By J. A. Jamieson, C. E.,† M. Can. Soc. C. E.

The comparatively recent change in the materials of construction of grain storage bins or silos has made the question of grain pressure one of great importance at the present time. Until within a comparatively recent date practically all grain elevators on this continent were built of wood, the storage bins being of laminated or planked construction, formed by building a number of walls both longitudinally and transversely of the building. The walls were constructed of plank 2 ins. thick, laid flat and spiked one to the other, and from 6 to 8 ins. wide according to the quality of the material used and the size of bin required. The width of plank or thickness of wall decreased towards the top, and the walls were spaced 12 to 14 ft. apart in both directions, thus subdividing the storage space into deep bins 12 to 14 ft. square and 60 to 70 ft. deep.

So long as this construction and size of bin was maintained, there was no great urgency for knowing accurately the lateral pressures produced by grain, as the thickness or necessary strength of the walls to safely resist the lateral pressure, and the strength of the hopper bottoms of the bins to carry the vertical load, had been well established by practice. Further, with a wooden bin wall of sufficient strength to resist the lateral pressure, the wall had ample area as a column to carry the vertical grain load transmitted to it by friction. This form of bin construction has been in use practically from the inception of the grain elevator system on this continent, and in many respects is admirably adapted for the purpose.

The defect from a structural point of view was its lack of vertical rigidity, by reason of the shrinkage of the wood and the compressing of the many horizontal joints during the first loading of the bins, which usually amounts to a settlement of 12 to 18 ins. in 70 ft., thus necessitating very great care being taken to distribute the grain load when first filling the bins in order to prevent undue strain of the structure. When, however, the initial settlement has taken place, no further precautions are necessary.

The chief defect, however, of the wooden elevator is its liability to destruction by fire, involving heavy loss on the building and contents, and therefore high insurance premiums. The increasing cost of insurance and timber, combined with the great inconvenience and loss of business to transportation companies by the destruction of an important terminal elevator, created a sudden demand for fireproof buildings; and the consequent change in the materials of construction made it necessary that a more accurate knowledge of grain pressures under all working conditions should be obtained to permit of the intelligent design of bins of different materials or increased diameter and depth.

Notwithstanding that the modern elevator system had its inception, and has reached its highest development in

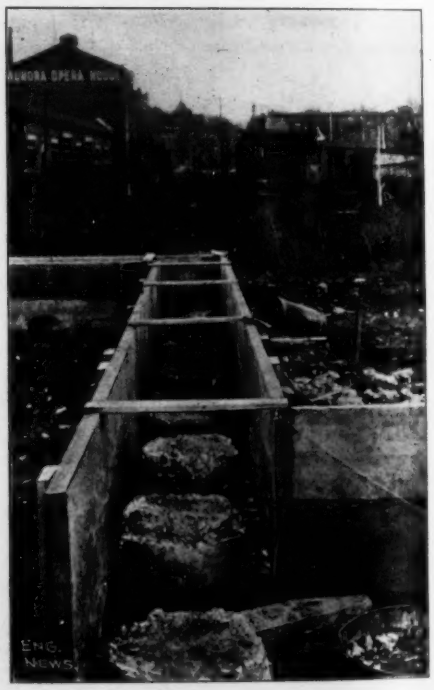


Fig. 18. View Showing Tops of "Raymond" Piles Driven for a Wall Foundation.

America, there is no record of any systematic series of tests having been made on this continent, with a view of obtaining a definite knowledge of the pressures produced by grain in deep bins. It has, however, been well understood by experienced grain elevator engineers that grain stored in bins of standard dimensions (12 to 14 ft. square and 60 to 70 ft. deep) produced comparatively small vertical and lateral pressures, and

*A paper read before the Canadian Society of Civil Engineers, December, 1903.

†Elevator Engineer, Board of Trade Bldg., Montreal, P. Q., Canada.

that much the greater part of the grain load in the bin is carried by the walls, and only a small part on the bin bottom, and that this is due to the friction between the grain and the bin walls. Very few, if any, have, however, realized to what extent this was governed by ratio of breadth to depth of bin, and the ratio of the horizontal area of the grain column to the area of the bin walls; and therefore to what extent the vertical and lateral pressures are increased, due to increase of horizontal dimensions of the bin. This lack of data by which to calculate the pressures and strength of grain storage bins of varying dimensions and materials of construction has been greatly felt by experienced grain elevator designers who have fully realized the importance of an ample factor of safety combined with economy of construction.

With a view to showing the difference between designing a bin or series of bins for the storage of grain or for the storage of a fluid, if we take a bin say 12 ft. square and 72 ft. deep, with a coefficient of friction between grain and the bin walls of .468, when filled with grain the vertical pressure will be only 15% and the horizontal pressure near the bottom only 9% of the pressure that would be produced by a fluid of the same specific gravity as grain. Therefore the bin bottom will only require to be 15% of the strength to carry the vertical load and the walls to resist the horizontal pressure only 9% of the strength. The walls, however, require to have sufficient strength acting as a column to support over 80% of the total weight of grain in the bin, while if used for the storage of a fluid, the walls would have no load to carry beyond their own weight. On the other hand it is quite practicable to design and build a tank or stand-pipe that will have an ample margin of safety when filled with water, and that would undoubtedly fail when used for the storage of grain.

In order to show the importance of the question from a financial standpoint, it may be stated that if the bin structure of the Montreal Harbor Commissioners elevator was designed and built to safely withstand fluid pressure and at the same time safely carry the grain loads, the cost would be at least $200,000 greater than if designed for the storage of grain with a factor of safety of 4.

In view of the lack of accurate published data on which to base calculations for the strength of grain storage bins, the serious losses that have occurred and the consequent lack of confidence caused thereby, the author believes that all engineers and owners interested in grain elevators and the storage and handling of grain, will agree that a full investigation and systematic series of tests to ascertain the manner in which grain loads are carried and the pressures produced by grain, are very urgently required. The author therefore proposes to present as clearly and briefly as possible the information gained by conducting a systematic series of tests, calculations, and investigations, to ascertain all possible information on this subject.

Before proceeding to describe these tests the author will briefly outline such different tests, calculations and discussions on this subject as it has been possible to obtain from any hitherto published records.

In Great Britain in the year 1882, Isaac Roberts made a series of tests on both model and full-sized bins, which demonstrated that in a grain bin having a depth equal to 4½ times the diameter, the proportion of the grain weight resting on the bin bottom was very small, as also the lateral pressure. Mr. Roberts read a paper describing his tests before "The British Association for the Advancement of Science." The author, however, regrets that he has been unable to obtain a full copy of this paper.

In 1895, H. A. Janssen, C.E., Bremen, Germany, made a number of experiments on small rectangular bins with a view to obtaining the proportion of weight of the grain contained in a bin that would rest on the bottom, and that would be carried by the bin walls. His bins were all of approximately the same depth but of varying horizontal areas. Briefly, his system of tests consisted in supporting bin walls on four jackscrews while in the bottom of the bin was placed a loosely-fitting board resting on a platform scale. By filling the bin with grain the proportion of weight resting on the bottom was recorded on the scale. When the weights previously placed on the beam balanced the weight of grain resting on the bottom a record was taken of both the weight of grain in the bin and the proportion of said weight that was resting on the bottom. The bin was then slightly raised by means of the jackscrews, and owing to the friction of the grain on the bin sides this also relieved part of the bottom pressure and allowed the beam to drop; added weights were then placed on the beam and the filling of the bin proceeded with, the same procedure being followed until the bin was filled. Janssen's tests were thus carried out in four different sizes of bins, but were to obtain the bottom pressure only, as he found that having obtained the bottom pressures, it was quite simple to calculate the lateral pressure. By conducting a series of tests to obtain the coefficient of friction between grain and the bin wall materials, he was enabled with the information thus gained to calculate pressures in different sized bins.

His experiments seem to have been very carefully and scientifically carried out, and his apparatus well adapted for the purpose. The results which he obtained are almost identically the same as those obtained by the author. The full description of Janssen's tests is published in "Der Zeitschrift Des Vereins Deutscher Ingenieure," 1895, Vol. XXXIX., page 1045.

In 1896 there was published in the same journal, p. 1122, a description of certain tests made by one Prante at Bernburg. Prante's tests were conducted with a view to obtaining the lateral pressure of the grain in a cylindrical bin, and appear to have been very unsatisfactory. In fact, from the author's experience, it would be very difficult, if not impossible, to obtain results of any value with the apparatus used. The chief interest in Prante's tests consists in the greatly increased pressure which he states he obtained with grain in motion, or while the grain was being drawn out of the bin. This was undoubtedly due to the weakness and unsuitability of his appliances, because, from the many observations and tests made by the author, no such increase of pressure could take place. The curves of pressure apparently obtained by him do not agree in any particular with any records of tests made by others. Prante himself states that his apparatus was found to be weak, and concludes as follows: "For the present I must leave the reader to consider the preceding tests, insufficient as they are, as a first contribution, which is to furnish an incentive to further and more accurate tests."

In 1897, Wilfred Airy, B.A., M. Inst. C.E., read a paper on "The Pressures of Grain" before the Institute of Civil Engineers, London, a full report of which is published in the Proceedings, Vol. CXXXI., 1897-98. While this paper is a valuable contribution on the subject of grain pressures, the question is treated from a theoretical point only. Mr. Airy appears to have been lacking in the necessary practical experience to enable him to take into consideration all the conditions which apply in actual practice. Mr. Airy first made tests with a view to obtaining the coefficient friction between grain and grain (or the angle of

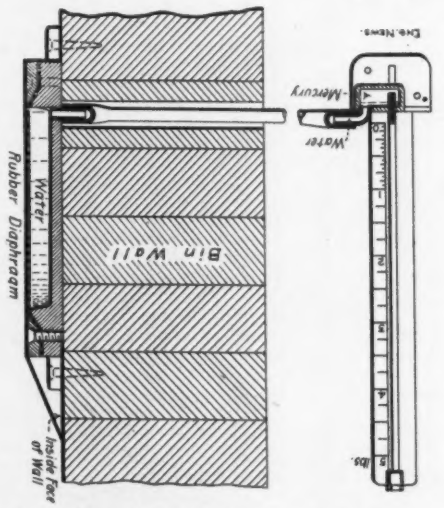


Fig. 1. Hydraulic Diaphragm Used for Grain-Pressure Tests in Full-Size Bins.

repose) and the different materials of which bins are usually constructed. From these data and the weight of the grain, he produced a formula for calculating the pressures in a bin of any given depth or breadth. This formula gives the maximum load on the bin bottom when the depth of grain in the bin is equal to 3.5 times the breadth. As, however, a further depth of grain is added to the quantity already in the bin, the load on the bottom decreases until the grain ultimately reaches a depth when the only remaining weight on the bin bottom would be that of a pyramid or cone of grain whose sides were at the greatest angle of repose and the base equal to the horizontal area of the bin and all the balance of the weight of the column would be carried by the bin walls, thus entirely neglecting the important fact that the weight on the bottom having once obtained the maximum, cannot be decreased by any increase of lateral pressure, unless by slightly lowering the bottom.

In 1897 the failure of a coal bin in Paterson, N. J., started a discussion in Engineering News on the pressures produced by coal and other granular materials stored in shallow bins. This discussion was started by the Editor of Engineering News, and a number of engineers throughout the country contributed more or less valuable letters on the subject, but no records of actual tests were given, and since the discussion was confined almost entirely to shallow bins there is very little of it applicable to the deep bin problem.

At the beginning of the year 1900, it became apparent that wooden elevator construction must soon be replaced by buildings less liable to destruction by fire, and since this would involve entirely different materials of construction, the author realized that more accurate data were required to permit of intelligent and economical design of new construction. He therefore determined to conduct a series of tests with a view to gaining such information.

TESTS ON FULL-SIZED BINS.

On first consideration, the problem seemed almost too difficult to undertake on account of there being no known appliance suitable for the purpose of making the tests, and on account of the time and expense involved. The first and most difficult problem to be met was the design of the testing appliance to make the tests in a full-sized bin which would meet all requirements as to accuracy, decrease as well as increase of pressure due to the movement of the grain, and would record the pressure in different parts of a bin under all working conditions. Several styles of weight scale-levers and beams were first designed all of which were open to serious objection and the difficulty seemed unsurmountable until the author conceived the idea of using a hydraulic diaphragm and a mercury or water column gage, the first of which could be placed inside the bin at any given point either on the sides or bottom, with a tube leading through a small hole in the wall to the gage, and therefore ascertain the pressure per square inch either vertically or laterally at any point of the bin. This appliance was immediately designed, care being taken to get the pressure face of the diaphragm, which was made of pure sheet rubber, as large as practical, so that there would be no appreciable receding of the face by displacement of the water, owing to the pressure raising the mercury in the small gage glass. When this appliance was manufactured and tested, it was found to be an accurate and sensitive weighing machine, and it is believed that no more suitable or accurate testing gage can be found for the purpose. (See Fig. 1.)

On the 10th of April, 1900, and following days the tests were carried out in the full-sized bins of the Canadian Pacific Ry. elevator at West St. John, N. B., the inside dimensions of the bin being 12 ft. by 13 ft. 6 ins., and the depth above the hopper bottom, 67 ft. 6 ins.; the grain used was Manitoba wheat, weighing 49.4 lbs. per cu. ft.

The hopper bottom of the bin was first filled with grain and leveled off. To obtain the lateral pressure the diaphragms were then placed in position against the walls a short distance above the hopper bottom, with the face vertical; to obtain the vertical pressure they were placed on top of a small platform attached to the hopper bottom, with face horizontal.

The gages were set up in an adjoining bin, a small rubber tube forming the connection between the diaphragm and the mercury cup of the gage, the diaphragm and tube being completely filled with water. The grain was then weighed and run into the bin in the usual manner, the first draft having a clear drop of 70 ft. Each draft weighed 30,000 lbs. and gave a depth of 3 ft. 9 ins. in the bin. The gage was closely observed as the grain was running in, and the maximum readings taken and recorded as each draft was complete, until the bin was filled. The gages and the grain were then allowed to remain for about 18 hours, at the expiration of which time there was practically no change in the reading of the gage. The grain was then drawn out of the bin and the gage closely observed and the readings recorded as each 30,000 lbs. were weighed out, the maximum readings during the draft being taken. The grain was drawn off at the rate of 9,000 bushels per hour. The pressures fluctuated considerably as the grain was being drawn out, with a maximum increase of 4% over that obtained when filling the bin or when the grain was at rest. The position of the diaphragm was then changed to near the corner of the bin and the above procedure repeated with practically the same readings as in the first test. During the running out test, the valve was suddenly closed several times, stopping the downward movement of the grain; this gave a slight increase of pressure, and when the valve was again opened a corresponding decrease of pressure.

The pressures obtained, both vertical and lateral, were then plotted, the maximum readings of the different tests being used. The plottings and curves obtained are shown in the diagram marked A, in Fig. 7, and the pressures per square inch both on the bin bottom and against the walls are given in the accompanying Table I., which also shows the total side pressure, the relative vertical and lateral pressures and the coefficient of friction between grain and walls. The column of "Equivalent Fluid Pressure" shows the pressure that would be produced by a fluid of the same specific gravity as the grain due to the different heads, or in other words, the pressures which would exist if there was no friction between the grain and the bin walls.

TESTS IN MODEL BINS.

The preceding described tests in the full-sized bins of the Canadian Pacific Elevator at St. John, N. B., gave all the data necessary to proceed with confidence with the designing of bins of approximately the same dimensions as the ones in which the tests were conducted. There still remained, however, considerable data to be obtained in order to devise a formula or system of calculating the pressures, and the proportion of grain weight that would be carried by the sides and on the bottom of bins of any ratio of breadth to depth or constructed of different materials.

After fully considering the question, the author believed that all the necessary data could be obtained by conduct-

ing a series of tests in model bins. This was undertaken in the winter of 1902-03, and the following testing apparatus was designed and manufactured:

One bin 12 ins. square, 6 ft. 6 ins. deep, the sides being made of corrugated or trough plate steel (corrugations running horizontally) attached to corner columns.

One bin 12 ins. square, 6 ft. 6 ins. deep, made of smooth wood boards.

One of the same dimensions as the last with the boards roughened on the inside of the bin, to imitate a bin of ordinary wooden cribbed construction.

One of the latter bins was also lined with flat steel plates to imitate a square steel bin.

One wooden bin 6 ins. square, 6 ft. 6 ins. deep.

One round steel bin 6 ins. diameter and 6 ft. 6 ins. deep.

One round steel bin 12 ins. diameter and 6 ft. 6 ins. deep.

Six hydraulic diaphragms: One being 12 ins. square, one 12 ins. in diameter, one 6 ins. square, one 6 ins. in diameter, one rectangular 3 x 12 ins., and one 2 ins. square.

In testing for bottom pressure the diaphragms were the full size of the different bins, forming a complete bottom for them. The total weight of grain coming on the bottom therefore rested directly upon a thin sheet of pure rubber, which in turn rested on the water contained in

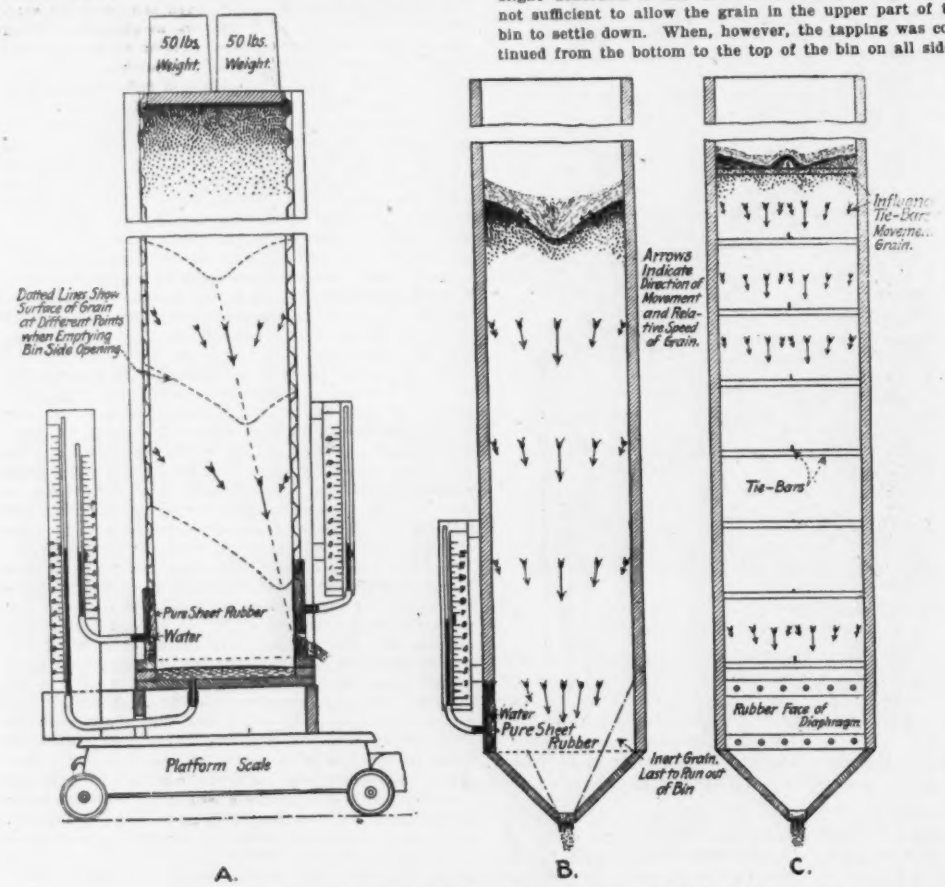


FIG. 2. ARRANGEMENT OF APPARATUS IN MODEL-BIN TESTS.

the diaphragm, while the bin itself rested upon the frame of the diaphragm. Connection was made between the diaphragm case and the glass gage column, which was set vertically alongside of a measuring scale. To obtain the lateral pressure the diaphragm was made to form part of the bin wall, the face being set vertical and in line with the inside face of the bin. (See diagram of arrangement of test bins, Fig. 2.)

The whole apparatus was set on a platform scale so that the weight of grain could be accurately taken as the bin was filled. The measuring scale was then adjusted accurately to the height of water in the gage glass. Grain was then poured into the top of the bin in drafts varying from 25 to 6¼ lbs. each, according to the size of bin used, and readings of the height of water column in the gages taken and recorded at each draft as the bin was filled.

Tests for bottom or vertical pressure were made in all the different bins, and for lateral pressure in a majority of the bins.

In the square trough-plate or corrugated-steel bins, tests were made with the following varieties of grain: Wheat, peas, corn or maize, and flax-seed; and in the cylindrical bins, tests were also made with thoroughly dry, clean river sand. The grain used was the highest grade that could be procured and was thoroughly clean and commercially dry; the wheat was No. 1 Manitoba Hard, weighing 50 lbs. per cu. ft., peas weighed 50 lbs., corn 45 lbs., and flax-seed 41.5 lbs. The sand weighed 100 lbs. per cu. ft. The weights as above were all carefully ascertained by means of the Grain Testers' Balance. Wheat was used to conduct the full series of tests, while the other grains were only tested in two of the bins, with a view to establishing the comparative pressures with wheat, over 50 separate tests being made in all. Some of the tests are given in full in the accompanying Tables IV. to VIII., and the curves Figs. 5 to 8.

The tests were all carried out in duplicate. After the first series were completed, the readings plotted and calculations extended, the second series were undertaken with a view to checking the first, and to gain such additional information as was found to be desirable. In the first series the grain was poured into the bin from a pail, while in the second series of tests a funnel with a large opening was used. This did not make any difference in the maximum pressures obtained, but the latter mode of filling the bin gave very accurate curves when plotting the diagrams, while the plottings from the first series were in some instances somewhat erratic.

TESTS UNDER SPECIAL CONDITIONS.

With a view to ascertaining the effect of vibrations or shocks on the pressures, the sides of the bin were sharply tapped with a hammer. It was found that by tapping the bin near the bottom only, the pressure or load on the bottom could be decreased. This was found to be due to a slight deflection in the bin sides, which, however, was not sufficient to allow the grain in the upper part of the bin to settle down. When, however, the tapping was continued from the bottom to the top of the bin on all sides, the grain in the bin could be settled from 2 to 3 ins., giving a slightly increased pressure on the bottom. In test No. 1A, the full records of which are given in Table IV., it will be noted that the settling of the grain amounted to 2¼ ins., giving a maximum reading of 10⅛ ins. of water, or an increase due to the shock of 1¾ ins. of water, equal to total increased weight on bottom of approximately 9 lbs. It may be stated that this shock was proportionately very much greater than could be produced under ordinary conditions in large elevator bins.

The author may state here that while vibration or shock will slightly increase both the vertical and lateral pressure, as the lateral pressure increases the total friction on the wall will correspondingly increase and therefore there cannot be found any good reason for assuming any *material* increase of pressure due to shocks. Again, by slightly raising the bin with screws inserted between the frame of the diaphragm and the bottom of the bin walls, the pressure on the bottom could be very materially decreased. This decrease, allowing the water in the gage to recede from the maximum of 10⅛ ins. to 7 ins., clearly shows that the greater the pressure on the sides the greater the load carried by the walls.

On the bin being again lowered to its original position, while no increase of lateral pressure was shown by the side diaphragm, there was a very large increase of pressure on the bottom diaphragm, or sufficient to cause the water to flow out of the top of the 4-ft. gage glass tube, which was not therefore long enough to record the pressure; in fact, the total weight of the grain was then resting on the bottom diaphragm, and in addition the grain was acting as a column to support the weight of the bin itself.

Again, by placing standard weights of 50 lbs. each on top of the grain, the pressure on the bottom would be only slightly increased by each weight applied, and it decreased again as the weights were removed. This experiment was repeated a number of times, in one case 400 lbs. of weights being applied, with practically the same results in every case; indications clearly that the increased pressure on the bottom by the application of weights on the top of the grain, was due to a slight vertical compression of the bin walls, or the elasticity of the grain.

Very careful tests were also made to ascertain the pressure due to grain in motion, or when the grain was being drawn out of the bin. To obtain the bottom pressure, the grain was drawn from an opening in the side of the bin close to the bottom. There was found to be a decrease of pressure on the bottom when the gate was opened and this decrease was maintained until the bin was about half emptied, then it became approximately the same as when the bin was being filled. Near the bottom the pressures showed an increase over the curve obtained when filling the bin; this, however, was entirely due to the necessity of drawing the grain from the one side of the bin, as when nearly emptied, the remaining grain was all on one side of the bin and therefore nearly all resting on the bottom.

When the grain was being drawn from the opening at the side of the bin, it was found that there was considerable difference in lateral pressure on the different sides. On the side directly opposite to the opening there was a large increase of pressure, and on the same side as the opening the pressure decreased to less than half when the 3-in. x 12-in. rectangular diaphragm was being used; and when the 2-in. square diaphragm was placed directly over and a short distance above the opening, there proved to be practically no lateral pressure at this point. (See Fig. 8.)

When the bin is being filled or when the grain is being drawn from the opening of a square or cylindrical bin through an opening exactly in the center, a line drawn vertically through the center of the bin is the center of pressure, and the lateral pressure per square inch is equal on all sides of the bin. If, however, the grain should be drawn from an opening in the side of the bin, or in the bottom close to the side, then, owing to the moving column of grain being over the opening, the center of pressure is changed, and the lateral pressure is considerably increased on the side opposite to the opening and decreased on the side over the opening, thus throwing very uneven strains into the bin walls. In a square bin, this will simply throw the increased pressure on the far wall, but in a cylindrical bin this must have a very injurious effect, unless the walls should be of very rigid construction. In a steel tank, the walls of which are very thin and have practically no rigidity, this uneven pressure tends to throw the tank considerably out of round, while the decreased pressure on the side over the opening makes this part of the tank shell very unstable as a column to carry the vertical load, with the result that steel tanks often buckle inward at varying distances above the opening. This conclusively shows that in all bins, and especially in those of cylindrical shape, to avoid these excessive strains the grain should always be drawn from an opening in the center of the bin.

To properly ascertain the lateral pressure when the grain was being drawn from an opening in the center (which is the usual manner in small bins) the bin was provided with a hopper bottom, with the gate opening directly in the center, the diaphragm being placed on the side as before. The grain was then drawn out and weighed, the gage carefully observed, readings recorded at the end of each draft, or when the gate was closed, and to ensure getting all fluctuations of pressure, two or three intermediate readings were taken while the grain was in motion. Several similar tests were made with varying sizes of gate openings and grain running out at speeds varying from 50 lbs. to 120 lbs. per minute, and the increase of lateral pressure due to grain in motion over grain at rest, or when the bin was being filled, was found to vary from 5% to 9.3%, the latter being for the highest speed, which is, however, relatively much greater than would be attained in practice in full-sized bins.

Tests were also made by pouring grain in at the top at varying speeds, while it was being drawn out at the bottom, but this was found to have no appreciable effect until the bin was nearly emptied, and the pressure had considerably decreased. By pouring grain in at a higher speed than it was being drawn out, the pressure could be again raised, but in no case beyond the maximum of 9.3% over that obtained while filling the bin.

If the grain is drawn from the center of the bin, it may be safely stated that the increase of pressure due to the grain in motion, over grain at rest, or when the bin is being filled, will not exceed 10% and the increase will be considerably less than this when the ratio of the area of the gate opening to the area of the bin is 1 to 150, which is approximately the usual practice in standard-sized bins.

That no large increase of pressure actually takes place due to grain in motion, when the grain is being drawn

from the center of the bin bottom is, I believe, fully demonstrated by the above tests, and also by the tests in the full-sized bins at St. John, N. B. In addition, the author has on three different occasions made careful measurements of the deflection of the walls of different elevator bins, 1, when they were being filled; 2, after the grain had been at rest for several days, and, 3, when the grain was being drawn out. One of the records is as follows:

Bin filled with wheat. Cribbed spruce walls. Thickness of wall, 6¾ ins. Clear span 13 ft. 5¼ ins. Depth of grain in prism of bin, 65 ft. Height of grain above point of measurement for deflection, 60 ft. Deflection when first loaded, ⅝-in. Deflection when four days under load, 11-16-in. When grain was being drawn out, the deflection varied from ⅝-in. to a maximum of slightly under ¾-in., the latter deflection being when the gate was suddenly closed.

Careful calculations were made for the fiber stress in the walls, and it was found that this deflection would be

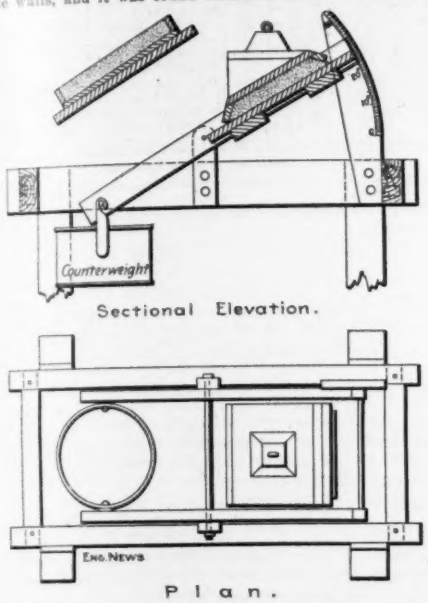


Fig. 3. Apparatus for Obtaining Angle of Repose and Coefficient of Friction of Grain Against Bin Wall.

approximately equal to a distributed load of 352 lbs. per square foot of wall.

Tests were also conducted with a view to ascertaining the complete movement of the grain when it was being drawn out and to find relative speed of the downward movement of the grain at different points in the bin. To facilitate this, the bin was provided with a glass side, and different colored grains placed at equal distances apart vertically. The gate was then opened and the movement of the grain down the glass side observed and the time taken when each of the colored grains came out of the bottom. It was found that a column of grain directly over the opening in the center of the bin moved at the highest rate of speed, the vertical movement decreasing towards the sides, the whole column of the grain in the bin, however, moving downward. There was a small triangular section of grain at the bottom of the bin, which did not move out until the last. Thus, a part of the first grain put in the bin was the last to run out. (See sketch B, Fig. 2.)

TABLE I.—Grain Pressure Tests in Full-Size Bin.

Tests made with wheat in cribbed wooden bin, Canadian Pacific Ry., elevator at West St. John, N.B., Canada. Inside dimensions of bin, 12 ft. × 13 ft. 6 ins. = 23,328 sq. ins. Depth of bin, 67 ft. 6 ins. Wheat used for test, No. 1 Hard Manitoba, weighing 49.4 lbs. per cu. ft.. Weighed into bin in drafts of 30,000 lbs., giving each 3 ft. 9 ins. depth of grain in bin.

Grain in prism of bin..... 540,000 lbs.
Grain in hopper bottom ..... 16,500 "
Total grain in bin ..... 556,500 lbs.

Grain weighed into bin, in lbs.	Height of grain column, in ft. ins.	Equivalent fluid pressure, in lbs. per sq. in.	Pressure of grain: Vertical; on bottom, in lbs. per sq. in.	Pressure of grain: Side; at bottom of walls in lbs. per sq. in.	Pressure of grain: Total side; per section, in lbs.	Grain carried: On bottom: Weight, lbs.	Grain carried: On bottom: Total weight, %.	Grain carried: On sides: Weight, lbs.	Grain carried: On sides: Total weight, %.
30,000	3 9	1.286	1.118	0.343	9,446	26,081	86.9	3,919	13.1
60,000	7 6	2.573	1.948	0.938	25,832	45,443	75.7	14,557	24.3
90,000	11 3	3.859	2.499	1.517	36,270	58,297	64.7	31,704	35.3
120,000	15 0	5.145	2,927	1.615	44,477	68,291	56.9	51,719	43.1
150,000	18 9	6.431	3.247	1.804	48,682	75,746	50.4	74,254	49.6
180,000	22 6	7.718	3.482	2.011	55,382	81,228	45.1	98,772	54.9
210,000	26 3	9.004	3.635	2.111	58,136	84,797	40.3	125,203	59.7
240,000	30 0	10.290	3.752	2.201	60,615	87,527	36.4	152,473	63.6
270,000	33 9	11.576	3.843	2,278	62,736	89,650	33.2	180,350	66.8
300,000	37 6	12.863	3.924	2,345	63,581	91,539	30.5	208,461	69.5
330,000	41 3	14.149	3.987	2.381	65,672	93,009	28.1	236,991	71.9
360,000	45 0	15.435	4.041	2.417	66,564	94,268	26.1	265,732	73.9
390,000	48 9	16.721	4.077	2.435	67,059	95,108	24.3	294,892	75.7
420,000	52 6	18.008	4.095	2.453	67,555	95,528	22.7	324,472	77.3
450,000	56 3	19.294	4.113	2.453	67,555	95,948	21.3	354,052	78.7
480,000	60 0	20.580	4.129	2.453	67,555	96,321	20.1	383,679	79.9
510,000	63 9	21.866	4.129	2.462	67,803	96,321	18.8	413,679	81.2
540,000	67 6	23.153	4.129	2.462	67,803	96,321	17.8	443,679	82.2
					1,004,632				

Note 1.—When bin is full the distribution of loads is as follows:

Vertical pressure	96,321 lbs.
Grain in hopper	16,500 "
Total load on hopper bottom	112,821 lbs.
Total vertical load carried by bin walls	443,679 lbs.
Total grain in bin.....	556,500 lbs.

Note 2.—Relative Vertical and Lateral Pressure.—Total pressure on bottom due to 67 ft. 6 ins. grain = 4.129 lbs. per sq. in. multiplied by area of bottom, 23,328 sq. ins. = 96,321 lbs. Maximum pressure on side of bin due to 67 ft. 6 ins. grain = 2.462 lbs. per sq. in. Lateral pressure—59.6% of vertical pressure, or vertical pressure = 1.66 lateral pressure. Coefficient of friction between grain and sides of bin

$$= \frac{\text{Weight carried by sides}}{\text{Total side pressure}} = \frac{443,679}{1,004,632} = .441.$$

Tests were also made by placing small ½-in. by 24-gage steel bars across the center of the bin in both directions, spaced 6 ins. apart vertically, the bars being set on edge with a view to presenting the least resistance to the moving grain column. (See sketch C, Fig. 2.) It was found that the bars had a very decided effect on the vertical movement of the grain; in fact, ⅓ less grain would run through the opening at the bottom in a given time, as in the same bin with the same opening, without tie bars. This shows that when the grain is moving down a very heavy strain must be thrown into the tie bars, and through the tie bars into the walls; that the vertical grain load carried by the walls will be considerably increased; and that tie bars, if used at all, should not run across the center of a bin. All tie bars or other obstructions, however, in a bin will be subjected to considerable strain and should be avoided if at all possible.

All the above tests were made in bins 12 ins. square and 12 ins. diameter by 6 ft. 6 ins. deep, and it was found that with the walls giving the same coefficient of friction and having the same ratio of wall area to horizontal area of the bin, there was practically no difference in pressure between the square and cylindrical bins. The pressure varied, however, directly as the coefficient of friction, taking as an example:

Test No. 1A, Table IV., Bin. 12 ins. square, horizontally corrugated steel sides; wheat in bin, 325 lbs.; weight on bottom, 45.46 lbs.; coefficient of friction, 0.468.

Test No. 5A, Table V., Bin 12 ins. square, flat steel plate sides; wheat in bin, 325 lbs.; weight on bottom, 60.397 lbs.; coefficient of friction, 0.355.

The latter gave vertical and lateral pressures 32.9% greater than the former, and the walls of the former bin carried 4.88% more of the total weight of the grain in the bin than the latter.

A test was made by using a stout canvas bag or cylinder 12 ins. in diameter, 6 ft. 6 ins. deep, provided with metal rings at both ends, one ring attached to the metal frame of the 12-in. circular diaphragm. It will be noted that this formed a cylindrical bin with wall incapable of supporting any vertical load. The bag was extended to full height and the wheat poured in at the top. When the bag was full, it was found that the height of water in the gage glass multiplied by the area of the diaphragm gave 1½ lbs. more than the total weight of grain, showing that the grain column was supporting a part of the weight of the bag, which weighed 3¼ lbs., and incidentally proving the correctness of the hydraulic diaphragm and water column as an accurate weighing machine.

A test was also made in the 12-in. diameter cylindrical bin, using sand instead of grain. The sand was thoroughly dry, clean and of good building quality; angle of repose, 34°; weight, 100 lbs. per cu. ft. When 537½ lbs. were put into the bin, it was found that 99.211 lbs. or 18.45% was resting on the bottom and 438.289 lbs. or 81.55% carried by the sides. (It is interesting to note that both sand and wheat gave approximately the same percentage of total weight resting on the bin bottom or diaphragm. The wheat weighed 50 lbs. per cubic foot and gave 18.29% on the bottom and 81.71% carried on the sides.) By sharply tapping the cylinder on both sides with the hands, we settled the sand 3 inches, increasing the load on the bottom to 120.272 lbs. or 22.37% of the total weight of sand in the bin.

In conducting the tests, the coefficient of friction between the grain and the bin walls was readily obtained in the following manner: Having found the total grain weight resting on the bottom of the bin, we deduct this bottom weight from the total weight of the grain in the bin. This gives the weight supported by the walls, and by dividing this weight into the total side pressure, we get the coefficient of friction. The total side pressure was obtained by multiplying the pressure per square inch for each section of the bin, by the area of the walls for that section, and the sum of the pressures per section give the

TABLE III.—COMPUTED PRESSURES OF WHEAT, IN BINS 10 × 10 FT. AND 20 × 20 FT., 80 FT. DEEP.

Lateral pressure = 0.6 × vertical pressure. Weight of wheat, 50 lbs. per cu. ft. Angle of repose, 28°; l = 0.6 V. Coefficient of friction between grain and bin walls = 0.41667.

Height of grain.	10 × 10 ft. bin.: Weight in bin, lbs.	Carried by Sides: Per ft., lbs.	Carried by Sides: Total, lbs.	Carried by Bottom: Per ft., lbs.	Carried by Bottom: Total, lbs.	Pressure per sq. in., lbs. Step process: Lateral.	Step process: Vertical.	By pressure factors: Lateral.	By pressure factors: Vertical.
1 ft.	5,000	000	0,000	5,000	5,000	0.00	0.35	0.00	0.29
2 "	10,000	500	500	4,500	9,500	0.21	0.67	0.13	0.67
3 "	15,000	950	1,450	4,050	13,550	....	....	....	....
4 "	20,000	1,355	2,805	3,645	17,105	....	....	....	....
5 "	25,000	1,720	4,525	3,280	20,475	0.72	1.43	0.67	1.38
6 "	30,000	2,048	6,573	2,952	23,427	....	....	....	....
7 "	35,000	2,343	8,916	2,657	26,084	....	....	....	....
8 "	40,000	2,608	11,525	2,392	28,475	....	....	....	....
9 "	45,000	2,848	14,373	2,152	30,627	....	....	....	....
10 "	50,000	3,063	17,436	1,937	32,564	1.28	2.28	1.26	2.16
15 "	75,000	3,856	35,296	1,144	39,704	1.61	2.78	1.61	2.67
20 "	100,000	4,325	56,080	675	43,920	1.80	3.07	1.81	2.96
25 "	125,000	4,601	78,591	399	46,409	1.92	3.25	1.94	3.14
30 "	150,000	4,764	102,120	236	47,880	1.99	3.35	2.01	3.28
35 "	175,000	4,861	126,252	129	48,748	2.03	3.41	2.07	3.38
40 "	200,000	4,918	150,740	82	49,260	2.05	3.45	2.10	3.44
45 "	225,000	4,952	175,437	48	49,563	2.06	3.47	2.11	3.48
50 "	250,000	4,971	200,258	29	49,742	2.07	3.48	2.12	3.51
55 "	275,000	4,983	225,152	17	49,848	2.08	3.49	2.12	3.53
60 "	300,000	4,990	250,090	10	49,910	2.08	3.49	2.13	3.54
65 "	325,000	4,994	275,053	6	49,947	2.08	3.50	2.13	3.55
70 "	350,000	4,997	300,032	3	59,968	2.08	3.50	2.14	3.56
75 "	375,000	4,998	325,019	2	49,981	2.08	3.50	2.14	3.57
80 "	400,000	4,999	350,012	1	49,988	2.08	3.50	2.15	3.58
Maximum.....		5,000		0	50,000	2.08	3.50		

Height of grain.	20 × 20 ft. bin.: Weight in bin, lbs.	Carried by Sides: Per ft., lbs.	Carried by Sides: Total, lbs.	Carried by Bottom: Per ft., lbs.	Carried by Bottom: Total, lbs.	Pressure per sq. in., lbs. Step process: Lateral.	Step process: Vertical.	By pressure factors: Lateral.	By pressure factors: Vertical.
1 ft.	20,000	000	000	20,000	20,000	0.00	0.34	0.00	0.00
2 "	40,000	1,000	1,000	19,000	39,000	0.21	0.66	0.00	0.62
3 "	60,000	1,950	2,950	18,050	57,050	....	....	....	....
4 "	80,000	2,853	5,803	17,147	74,197	....	....	....	....
5 "	100,000	3,710	9,513	16,290	90,487	0.87	1.54	0.56	1.59
6 "	120,000	4,524	14,037	15,476	105,963	....	....	....	....
7 "	140,000	5,298	19,335	14,702	120,665	....	....	....	....
8 "	160,000	6,033	25,368	13,967	134,632	....	....	....	....
9 "	180,000	6,732	32,100	13,268	147,900	....	....	....	....
10 "	200,000	7,395	39,495	12,605	160,505	1.54	2.73	1.34	2.76
15 "	300,000	10,247	85,317	9,753	214,683	2.14	3.65	2.02	3.67
20 "	400,000	12,453	143,395	7,547	256,605	2.59	4.36	2.51	4.33
25 "	500,000	14,160	210,955	5,840	289,045	2.95	4.91	2.91	4.90
30 "	600,000	15,481	285,955	4,519	314,145	3.23	5.34	3.21	5.34
35 "	700,000	16,504	366,434	3,496	333,566	3.44	5.67	3.46	5.64
40 "	800,000	17,295	451,405	2,705	348,595	3.60	5.93	3.63	5.89
45 "	900,000	17,907	539,779	2,093	360,221	3.73	6.12	3.75	6.10
50 "	1,000,000	18,380	630,780	1,620	369,220	3.83	6.28	3.87	6.28
55 "	1,100,000	18,747	723,818	1,253	376,182	3.91	6.40	3.96	6.43
60 "	1,200,000	19,030	818,430	970	381,570	3.97	6.49	4.02	6.55
65 "	1,300,000	19,250	914,262	750	385,738	4.01	6.56	4.08	6.67
70 "	1,400,000	19,319	1,011,041	581	388,959	4.05	6.61	4.14	6.76
75 "	1,500,000	19,551	1,108,544	449	391,456	4.07	6.66	4.18	6.82
80 "	1,600,000	19,652	1,206,612	348	393,388	4.09	6.69	4.20	6.88
Maximum.....		20,000		0	400,000	4.17	6.94		

total pressure on the bin walls. The coefficient of friction obtained in the above manner agreed very closely in every case with the coefficients obtained by means of the apparatus shown in Fig. 3.

To obtain the relative pressures due to increased breadth or diameter of bin, tests were made in the bins 6 ins. square and 6 ins. diameter, by 6 ft. 6 ins. deep. It was found in each case that the pressures per square inch, both vertical and lateral, in the larger bins were approximately twice as great as in the smaller bins, and that the weight resting on the bottom of the larger bins was approximately 8 times as great as in the smaller bins, or twice as great as the sum of the weight for four 6-in. bins. It was the author's original intention to have made tests in bins 18 ins. and 24 ins. square, to ascertain if the relative increase in pressure would vary with the breadth of the bin. This, however, was found to be unnecessary as it was readily seen that since the proportion of the grain weight carried by the sides was dependent upon the ratio of horizontal area, or the weight of the grain column, to the area of the bin walls, then if we increase the breadth and maintain the same ratio of breadth to depth, the pressure will increase directly as the breadth. As, however, the maximum pressures are reached at a depth of 3.5 times to 4 times the breadth, it may be stated that, approximately, both the vertical and lateral pressure will increase directly as the breadth.

ANGLE OF REPOSE AND COEFFICIENT OF FRICTION.

It is well known that if we pour grain upon a level floor it will assume the form of a cone, and if we endeavor to run grain through a spout, the spout must have a considerable angle before the grain will run, thus clearly indicating a considerable friction, both of grain on grain and between grain and the material of which the spout or bin wall may be constructed. It will be readily understood that if there was no friction between the grain and the bin walls, the total grain weight would rest on the bottom, and if there was no friction within the mass of grain, the horizontal pressure would be equal to that produced by a fluid of the same specific gravity as grain; it is this friction on the one hand and the lack of cohesion between the particles on the other, that distinguishes a granular mass from either a fluid or a solid. If the sides or walls of the bin are constructed of very smooth material or without any projections, the coefficient of friction between the grain and the walls will be considerably lower than if the walls were built of rough material, and the rougher the wall the higher will be the coefficient of friction until it may reach a maximum of grain on grain. As the form of the walls and the materials of construction have a great influence on pressures, it is necessary to establish both the coefficient of friction of grain on grain, and of grain on the sides of bins of different forms or constructed of different materials.

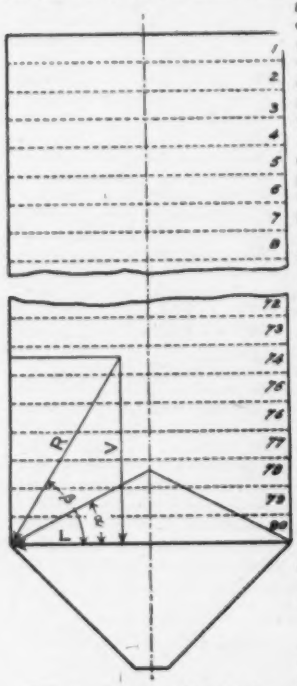


Fig. 4. Diagram Illustrating Relation Between Vertical and Lateral Pressures.

V = intensity and direction of vertical grain pressure;
L = intensity and direction of lateral grain pressure;
R = intensity and direction of resultant grain pressure;
α = angle of repose or natural slope of grain;
β = angle of shear

$$= 45° + \frac{\alpha}{2};$$

For wheat $\alpha = 28°$, $\beta = 50°$, $V = 1.665L$, $L = 0.6\ V$.

To enable these coefficients to be readily and accurately obtained, the author designed the simple apparatus shown in Fig. 3. To obtain the angle of repose of grain, the tray which is attached to the pivoted frame is filled and carefully leveled off and the frame balanced (see Fig. 3); the end holding the tray is then carefully raised until the first movement of the particles of the grain takes place and the angle carefully noted and taken as the angle of repose. By attaching to the pivoted frame a piece of any material of which bin walls may be constructed, and again filling a special tray with grain, the tray being inverted with the grain against the face of the bin material and tilting the frame as before, we find that, if the material is rough or has projections placed upon its face we can tilt the platform to a considerably higher angle than if the material is smooth. By carefully noting the angle of the first movement of the tray and the grain, and finding the tangent of the angle we obtain the coefficient of friction between grain and any material of which bin walls may be constructed. By placing weights on top of the tray, we have ascertained that the coefficient of friction remains approximately constant for pressures up to 5 lbs. per sq. in., which was about the limit of strength of our apparatus.

By careful tests in the manner above described, it has been found that different varieties of grain have angles of repose varying from 24° to 36° and that different samples of wheat will vary from 26° to 34°. The amount of moisture contained in the grain, and even a damp or dry day having considerable influence, the author therefore decided to adopt a No. 1 Hard Wheat, weighing 50 lbs. per cubic foot and an angle of repose of 28° as a standard, and which will be safe to use for all varieties of grain.

The coefficient of friction between standard wheat and different forms of walls built of different materials of construction, will vary considerably, but may be safely taken at the values given in the following table:

TABLE II.—Coefficient of Friction Between Wheat and Various Materials of Construction of Bin Walls.

Note.—Wheat used was the same as used for all pressure tests, No. 1 Manitoba Hard, weighing 50 lbs. per cu. ft.; angle of repose, 28°, or coefficient of internal friction equals 0.532.

	Coefficient of friction.
Wheat on wheat	0.532
" " steel trough-plate bin	0.468
" " " flat plate, riveted & tie bars	0.375 to 0.400
" " " cylinders, riveted	0.365 " 0.375
" " cement-concrete, smooth & rough	0.400 " 0.425
" " tile or brick, smooth or rough	0.400 " 0.425
" " cribbed wooden bin	0.420 " 0.450

CALCULATION OF BIN PRESSURES.

It will now be clear that, since there is no cohesion between the grains forming the mass, we will have considerable horizontal pressure, but as there is considerable friction within the mass, the pressure will not be so great as that produced by a fluid of the same specific

TABLES OF TESTS ON GRAIN PRESSURE IN MODEL BINS. MADE BY J. A. JAMIESON, MONTREAL, P. Q., 1903.

TABLE IV.—WHEAT IN TROUGH-PLATE BIN, 12 × 12 INS. BY 6 FT. 6 INS. HIGH.

Weight of grain, 50 lbs. per cu. ft. = 62.2 lbs. per bushel. Each section of grain weighed in = 6 ins. high, weighing 25 lbs, and having a wall area of 288 sq. ins.

BOTTOM PRESSURE TEST.
12 × 12-in. diaphragm horizontally on bottom; = 144 sq. ins. area.

Grain weigh'd into bin.	H'ight of grain col'mn	Equivalent fluid pressure.	Pressure of grain on diaphragm.	Grain carried on bottom. Weight.	Grain carried on bottom. % of total weight of grain.	Grain carried on bin-side. Weight.	Grain carried on bin-side. % of total weight of grain.
lbs.	in.	in. water.	in. water	lbs.		lbs.	
25	6	4.81	3⅛	18.184	72.7	6.816	27.3
50	12	9.62	5⅞	28.575	57.1	21.425	42.9
75	18	14.43	6⅞	34.420	45.9	40.580	54.1
100	24	19.24	7⅞	38.966	38.9	61.034	61.1
125	30	24.05	7⅞	40.914	32.7	84.086	67.3
150	36	28.86	8 5/16	41.888	27.8	108.112	72.2
175	42	33.67	8⅞	42.863	24.5	132.137	75.5
200	48	38.48	8 15/16	43.837	21.9	156.163	78.1
225	54	43.29	8¾	44.161	19.6	181.839	80.4
250	60	48.10	8¾	44.161	17.6	205.839	82.4
275	66	52.81	8 15/16	44.486	16.1	230.514	83.9
300	72	57.62	8⅞	45.460	15.1	254.540	84.9
325	78	62.53	8⅞	45.460	13.9	279.540	86.1
Effect of 50lbs. of weights placed on top of grain column :—							
682	163.68	131.27	9¾	48.708	7.1	633.292	92.9

Increase of pressure on bottom by placing weights on top of grain column in bin :—

Weights.	Increases gauge reading From	To	Increases in Inches	lbs
lbs.				
50	8⅞	9⅛	¼	3,247
100	9⅛	10	⅜	3,247
150	10	10⅜	⅜	3,247
	Total increase		1⅛	9,741

When weights were removed gauge returned to 8⅞"

NOTE.—By sharply tapping sides of bin, grain settled 2¼" from top, and gave a maximum gauge reading of 10¼in. of water, equal to a load on bottom of 54,553lbs., or 16.78 % of total weight of grain in bin.

By raising bin by means of screws at the corners, the gauge receded to 7 inches.

SIDE PRESSURE TEST.
6 × 6-in. diaphragm vertically in side of bin; = 36 sq. ins. area.

Grain weighed into bin.	Height of grain column.	Equivalent fluid pressure.	Pressure of grain on diaphragm. ins. water	lbs. per sq. inch	Side pressure per section.	Grain carried on bin-sides. Weight.	Grain carried on bin-sides. % of total weight of grain.
lbs.	ins.	ins. water	ins. water	lbs. per sq. inch	lbs.	lbs.	
25	6	4.81	⅛	0.02255	6.494	6.816	27.3
50	12	9.62	2⅛	0.09020	25.978	21.425	42.9
75	18	14.43	3⅛	0.13981	40.265	40.580	54.1
100	24	19.24	4 5/16	0.16461	47.409	61.034	61.1
125	30	24.05	4⅛	0.17138	49.357	84.086	67.3
150	36	28.86	4⅛	0.17589	50.656	108.112	72.2
175	42	33.67	5	0.18040	51.955	132.137	75.5
200	48	38.48	5⅛	0.18491	53.254	156.163	78.1
225	54	43.29	5⅛	0.18491	53.254	181.839	80.4
250	60	48.10	5 5/16	0.18716	53.903	205.839	82.4
275	66	52.81	5⅜	0.18942	54.553	230.514	83.9
300	72	57.62	5⅜	0.18942	54.553	254.540	84.9
325	78	62.53	5⅜	0.18942	54.553	279.540	86.1
					Total Side Pressure	596.184	

Relative vertical and lateral pressures at bottom, when bin is full:

$$\frac{\text{vertical pressure}}{\text{lateral pressure}} = \frac{.31570}{.18942} = 1.67,$$

or lateral pressure equals 60% of vertical pressure.

Coefficient of friction between grain and sides of bin:

$$\frac{\text{Weight carried by sides}}{\text{Total side pressure}} = \frac{279.54}{596.184} = 0.468.$$

NOTE.—When grain was running out of bin at rate of 50 lbs per min., through opening in center of hopper bottom, the maximum side pressure was 5⁹/₁₆ ins. water, or 0.200695 lb. per sq. in. This represents 6% increase of pressure due to grain in motion.

TABLE V.—WHEAT IN SHEET-STEEL BIN 12 × 12 INS. BY 6 FT. 6 INS. HIGH.

Weight of grain, 50 lbs. per cu. ft. = 62.2 lbs. per bushel. Each section of grain weighed in = 6 ins. high, weighing 25 lbs., and having a wall area of 288 sq. ins. Bottom and side pressure tests made simultaneously.

BOTTOM PRESSURE TEST.
12 × 12-in. diaphragm horizontally on bottom; = 144 sq. ins. area.

Grain weigh'd into bin.	H'ight of grain col'mn	Equivalent fluid pressure.	Pressure of grain on diaphragm.	Grain carried on bottom. Weight.	Grain carried on bottom. % of total weight of grain.	Grain carried on bin sides. Weight.	Grain carried on bin sides. % of total weight of grain.
lbs.	in.	in. water.	in. water	lbs.		lbs.	
25	6	4.81	3⅛	20.132	80.52	4.868	19.48
50	12	9.62	6 5/16	32.147	64.29	17.853	35.71
75	18	14.43	7 5/16	39.291	52.38	35.709	47.62
100	24	19.24	8⅛	45.785	45.78	54.215	54.22
125	30	24.05	9¼	48.058	38.44	76.942	61.56
150	36	28.86	9⅞	51.630	34.42	98.370	65.58
175	42	33.67	10 5/16	53.578	30.61	121.422	69.39
200	48	38.48	10⅞	55.851	27.92	144.149	72.08
225	54	43.29	11⅛	57.800	25.68	167.200	74.32
250	60	48.10	11⅛	59.100	23.64	190.900	76.36
275	66	52.81	11⅛	59.740	21.73	215.252	78.27
300	72	57.62	11⅛	60.397	20.13	239.603	79.87
325	78	62.53	11⅛	60.397	18.58	264.603	81.82
			Carried on bottom	60,397	on sides	264.603	

Relative vertical and lateral pressures at bottom, when bin is full:

$$\frac{\text{vertical pressure}}{\text{lateral pressure}} = \frac{.41943}{.25030} = 1.66,$$

or lateral pressure equals 59.7% of vertical pressure.

Coefficient of friction between grain and sides of bin:

$$\frac{\text{Weight carried by sides}}{\text{Total side pressure}} = \frac{264.60}{745.55} = 0.355.$$

SIDE PRESSURE TEST.
6 × 6-in. diaphragm vertically in side of bin; = 36 sq. ins. area.

Grain weighed into bin.	Height of grain column.	Equivalent fluid pressure.	Pressure of grain on diaphragm. inches water.	lbs. per sq. inch	Side pressure per section.
lbs.	inches.	inches water.	inches water.	lbs. per sq. inch	lbs.
25	6	4.81	3⅛	0.03157	9.092
50	12	9.62	5⅛	0.11275	32.472
75	18	14.43	4⅞	0.15534	44.762
100	24	19.24	5	0.18040	51.955
125	30	24.05	5⅛	0.19844	57.150
150	36	28.86	7 11/16	0.21422	61.695
175	42	33.67	6⅛	0.22550	64.944
200	48	38.48	6 5/16	0.23677	68.191
225	54	43.29	6⅛	0.24128	69.490
250	60	48.10	6⅛	0.24579	70.788
275	66	52.81	6⅛	0.24805	71.436
300	72	57.62	6⅛	0.25030	72.087
325	78	62.53	6⅛	0.25030	72.087
				Total side pressure	745.552

NOTE.—By sharply tapping bin with hammer the grain settled 3 ins., and gave maximum readings as follows:

Bottom pressure = 13¼ ins. water = 0.47806 lbs. per sq.in., = 21.2% of fluid pressure.

Side pressure = 7 13/16 ins. water = 0.28187 lbs. per sq. in., = 12.49% of fluid pressure.

TABLES OF TESTS ON GRAIN PRESSURE IN MODEL BINS. MADE BY J. A. JAMIESON, MONTREAL, P. Q., 1903.

TABLE VI.—WHEAT IN WOODEN BIN 12 × 12 INS. BY 6 FT. 6 INS. HIGH.

Bin made of smooth boards. Weight of grain, 50 lbs. per cu. ft., = 62.2 lbs. per bushel. For bottom pressure test, each section of grain weighed in = 6 ins. high, weighing 25 lbs., and having a wall area of 288 sq. ins. For side pressure, test, first section of grain = 12 ins. high, weighing 50 lbs., wall area 576 sq. ins.; all succeeding sections = 4.8 ins. high, weighing 20 lbs., wall area, 230.4 sq. ins.

BOTTOM PRESSURE TEST. 12 × 12-in. diaphragm horizontally on bottom; = 144 sq. ins. area.

SIDE PRESSURE TEST. 12 × 12-in., diaphragm vertically in side of bin; = 144 sq. ins. area.

Grain weigh'd into bin	Height of grain column	Equivalent fluid pressure.	Pressure of grain on diaphragm.	Grain carried on bottom. Weight.	Grain carried on bottom. % of total weight of grain	Grain carried on bin-side. Weight.	Grain carried on bin-side. % of total weight of grain.
lbs.	in.	in. water.	in. water	lbs.		lbs.	
25	6	4.81	3⅜	19.483	77.93	5.517	22.07
50	12	9.62	6¾	20.594	61.04	19.476	38.96
75	18	14.43	7	36.368	48.49	38.632	51.51
100	24	19.24	7⅛	40.914	40.91	59.086	59.09
125	30	24.05	8⅛	42.863	34.29	82.137	65.81
150	36	28.86	8¼	44.811	29.87	105.189	71.13
175	42	33.67	8¼	46.110	26.35	128.890	73.65
200	48	38.48	9	46.759	23.37	153.241	76.63
225	54	43.29	9⅜	49.032	21.79	175.968	78.21
250	60	48.10	9⅝	49.682	19.87	200.318	80.13
275	66	52.81	9¾	50.656	18.42	224.344	81.58
300	72	57.62	9¾	50.656	16.88	249.344	83.12
325	78	62.53	9¾	50.656	15.58	274.344	84.42
				Carried on bottom 50.656		on sides 274.344	

Grain weighed into bin.	Height of grain column	Equivalent fluid pressure.	Pressure of grain on diaphragm.	Side pressure per section.	Grain running out, pressure of grain on diaphragm.
lbs.	ins.	ins. water.	ins. water. lbs per sq. inch.	lbs.	ins. water. lbs. per sq. inch.
50	12.00	9.62	2¾ 0.10373	59.748	2 0.07442
70	16.80	13.47	4¼ 0.15334	35.329	4¼ 0.15334
90	21.60	17.31	4½ 0.17138	39.496	5⅛ 0.20295
110	26.40	21.15	5⅛ 0.18491	42.603	5⅛ 0.20746
130	31.20	24.99	5⅞ 0.19619	45.201	5⅛ 0.20746
150	36.00	28.86	5⅛ 0.19844	45.720	5⅛ 0.21197
170	40.80	32.71	5⅞ 0.20070	46.240	6 0.21648
190	45.60	36.56	5⅛ 0.20295	46.760	5⅛ 0.21197
210	50.40	40.41	5⅛ 0.20521	47.279	6⅛ 0.22099
230	55.20	44.26	5⅛ 0.20746	47.799	6⅛ 0.22099
250	60.00	48.10	5⅛ 0.20746	47.799	6⅛ 0.22550
270	64.80	51.95	5⅛ 0.21197	48.838	6⅛ 0.22775
290	69.60	55.80	5⅛ 0.21197	48.838	6⅛ 0.22775
310	74.40	59.65	5⅛ 0.21197	48.838	6⅛ 0.22775
325	78.00	62.53	5⅛ 0.21197	30.020	7⅛ 0.21197
			Total side pressure. 687.108		

Relative vertical and lateral pressures at bottom, when bin is full:

$$\frac{\text{vertical pressure}}{\text{lateral pressure}} = \frac{.35178}{.21197} = 1.66,$$

or lateral pressure equals 60.3% of vertical pressure.

Coefficient of friction between grain and sides of bin:

$$\frac{\text{Weight carried by sides}}{\text{Total side pressure}} = \frac{274.34}{687.11} = 0.397.$$

NOTE.—By sharply tapping sides of bin, the grain settled 2⅞ ins. and gave a maximum reading of 11⅞ ins. water, = 20.56% of fluid pressure.

When grain was running out of bin at rate of 120 lbs. per minute through opening in center of hopper bottom, the maximum side pressure was 6⁹/₁₆ ins. water, or 0.22775 lbs. per sq. in. This represents 7.5% increase of pressure due to grain in motion.

TABLE VII.—WHEAT IN ROUND SHEET-STEEL BIN 12 INS. DIAMETER BY 6 FT. 6 INS. HIGH; BOTTOM PRESSURE TEST ONLY.

Weight of grain, 50 lbs. per cu. ft. = 62.2 lbs. per bushel. Each section of grain weighed in = 7.44 ins. high, weighing 25 lbs., and having a wall area of 280.5 sq. ins. Last section only half as large. 12-in. diameter circular diaphragm horizontally on bottom; = 113.1 sq. ins. area.

Grain weigh'd into bin.	Height of grain column.	Equivalent fluid press'r	Pressure of grain on diaphragm.	Grain carried on bottom. Weight.	Grain carried on bottom. % of grain weighed in.	Grain carried on bin sides. Weight.	Grain carried on bin sides. % of grain weighed in.
lbs.	ins.	ins. water.	ins. water.	lbs.		lbs.	
25	7.44	5.96	4⅛	16.833	67.33	8.167	32.67
50	14.88	11.92	6¾	20.594	53.48	23.476	46.52
75	22.32	17.88	8⅜	34.175	45.43	40.895	54.57
100	29.76	23.84	9⅛	38.001	38.00	61.999	62.00
125	37.20	29.80	10	40.806	32.64	84.194	67.36
150	44.64	35.76	10⅛	42.847	28.56	107.153	71.44
175	52.08	41.72	10⅝	44.632	26.64	130.368	74.36
200	59.52	47.68	10⅞	45.907	24.95	154.093	75.05
225	66.96	53.64	11⅛	46.927	23.07	178.073	76.93
250	74.40	59.65	11⅛	47.692	19.07	202.308	80.93
262½	78.00	62.54	11⅜	47.937	18.29	215.063	81.71
				Carried on bottom 47.937		on sides 214.563	

NOTE.—By sharply tapping sides of bin with hands, the grain settled 2⅝ ins. from top, and gave maximum reading of 13¼ ins. water, = 20.5% of fluid pressure.

TABLE VIII.—SAND IN ROUND SHEET-STEEL BIN 12 INS. DIAMETER BY 6 FT. 6 INS. HIGH; BOTTOM PRESSURE TEST ONLY.

Sharp, clean, Chateaugay River Sand, thoroughly dry, weighing 100 lbs. per cu. ft., angle of repose = 34°. Each section of sand weighed in = 3.63 ins. high, weighing 25 lbs. Last section only half as large. Circular diaphragm 12 ins. diameter, horizontally on bottom; = 113.1 sq. ins. area.

Sand weigh'd into bin.	Height of sand column.	Equivalent fluid pressure	Pressure of sand on diaphragm.	Sand carried on bottom. Weight.	Sand carried on bottom. % of total weight of sand.	Sand carried on bin sides. Weight.	Sand carried on bin sides. % of total weights of sand.
lbs.	ins.	in water	in water	lbs.		lbs.	
25	3.63	5.82	2½	24.000	96.00	1.000	4.00
50	7.26	11.64	10⅛	43.356	86.71	6.644	13.29
75	10.89	17.46	13⅛	65.598	74.13	19.402	25.87
100	14.53	23.28	16	65.290	65.29	34.710	34.71
125	18.16	29.10	18	73.452	58.76	51.548	41.24
150	21.79	34.92	19⅛	79.573	53.04	70.427	46.96
175	25.41	40.74	20⅛	84.163	48.09	90.837	51.91
200	29.05	46.56	21⅛	87.294	43.61	112.776	56.39
225	32.67	52.38	22⅛	80.284	40.12	134.716	59.88
250	36.30	58.20	22⅛	91.815	36.72	158.185	63.28
275	39.93	64.02	22⅛	93.345	33.94	181.655	66.06
300	43.57	69.84	23⅛	94.020	31.54	205.980	68.46
325	47.19	75.69	23⅛	95.895	29.50	229.105	70.50
350	50.82	81.48	23⅜	96.405	27.54	253.595	72.46
375	54.46	87.30	23⅛	96.660	25.77	278.340	74.23
400	58.08	93.15	23⅛	97.681	24.42	302.319	75.58
425	61.71	98.95	24⅛	98.191	23.10	326.809	76.90
450	65.34	104.77	24⅛	98.446	21.87	351.554	78.13
475	68.97	110.58	24⅛	98.446	20.72	376.554	79.28
500	72.60	116.40	24⅛	98.701	19.74	401.299	80.26
525	76.23	122.22	24⅛	98.956	18.84	426.044	81.16
537½	78.00	125.09	24⅛	99.211	18.45	438.289	81.55
				Carried on bottom 99.211		on sides 438.289	

NOTE.—By sharply tapping bin, sand settled 3 ins. from top, and gave maximum reading of 20¼ ins. of water, = 23.5% of fluid pressure.

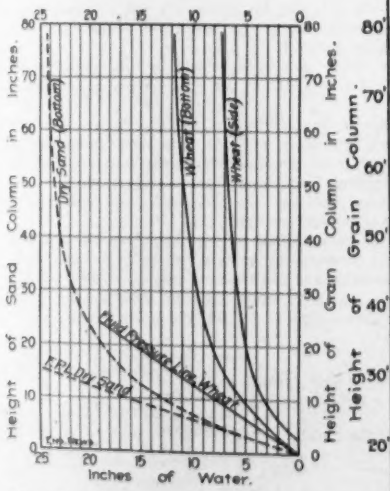


Fig. 6. Comparative Pressures of Wheat and Dry Sand.

Circular steel bin, 12 ins. diam. by 6 ft. 6 ins. deep.
Wheat, 50 lbs. per cu. ft.
Sand, 100 lbs. per cu. ft.

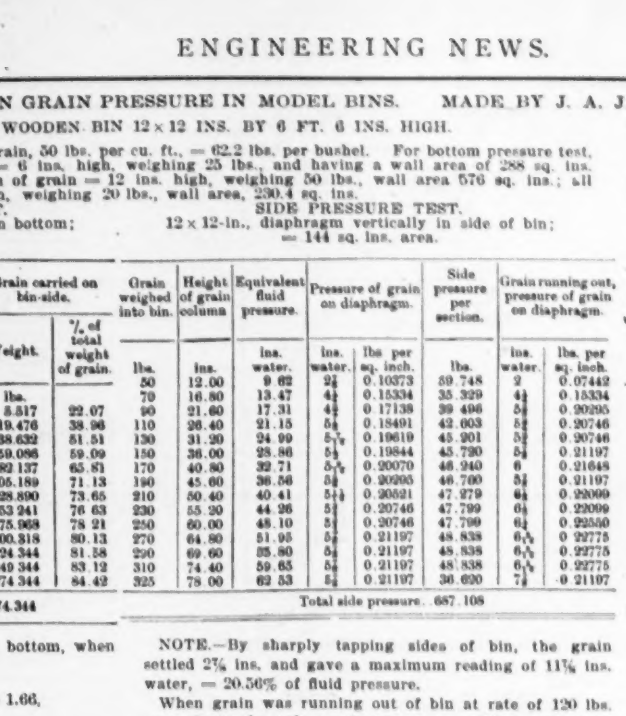


Fig. 7. Comparative Curves of Pressures in Full-Size and Model Bins.

A.—St. John Tests on Full-Size Bin.
Wheat in wooden bin, 12 ft. × 13 ft. 6 ins. by 67 ft. 6 ins. deep.
B.—Model Bin Tests.
Wheat in cribbed wooden bin, 12 ins. square by 6 ft. 6 ins. high.
C.—Model Bin Tests.
Wheat in wooden bin, 6 ins. square by 3 ft. 3 ins. high.

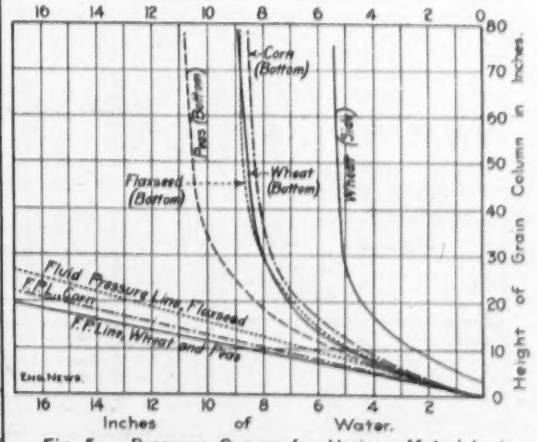


Fig. 5. Pressure Curves for Various Materials in Model Bin.

(Bin 12 ins. square by 6 ft. 6 ins. high. Bin sides made of trough-plate.)

gravity. Since there will be considerable friction between the grain and the confining walls, the pressure and the friction must cause the walls to carry a part of the load, and that the proportion of the weight which the walls will carry must increase as the pressure, and therefore when the total pressure against the circumference of the bin walls (say for one foot in depth), divided by the coefficient of friction, becomes equal to the total weight of the grain in that section, then there cannot be any further material increase of either vertical or lateral pressure. It is therefore evident that as the proportion of the weight of each layer carried by the wall is increased with the depth of grain, the ratio of depth to breadth is an important factor in determining the proportion of the total weight that will be carried by the walls and on the bin bottom; and again, since to support a given weight will require a given area of wall, with a given pressure per unit of area, and coefficient of friction, it is evident that the area of the walls must bear some definite relation to the horizontal area of the bin.

The proportion of the total weight of grain in a bin that would be carried by the walls and on the bottom of the bin, and therefore the intensity of both the vertical and lateral pressures produced by grain is entirely dependent upon the following factors: (1) The coefficient of friction between grain and the bin walls. (2) The ratio of the breadth or diameter of the bin to the depth. (3) The ratio of the horizontal area or weight of the grain column to the area of bin walls. (4) The angle of repose of grain, or the ratio of the lateral to the vertical pressure (see diagram Fig. 4).

With an angle of repose of 28°, as for wheat, the ratio of lateral to vertical pressure will be 0.6, which agrees accurately with the results of the tests.

The coefficient of friction will vary with the form and material of the bin wall, and we will select 0.41667 in order to simplify calculations, since 0.6 × 0.41667 = 0.25.

Having now established the factors and their values which govern the pressures produced by grain, it becomes a comparatively easy problem in simple arithmetic to determine the vertical and lateral pressures and the proportion of the weight of the contents of a bin of any given breadth and depth, or of any construction of walls, that will be carried by the walls and on the bin bottom. For the purpose of illustrating this method, we will assume a bin 10 ft. square, 100 sq. ft. horizontal area, filled with wheat weighing 50 lbs. per cu. ft.; each layer one foot thick will contain 100 cu. ft. weighing 5,000 lbs. and the area of the four walls for one foot in depth of bin, will be 40 sq. ft.

Starting with the top layer, we find that the lateral pressure, and therefore the friction between the grain and the

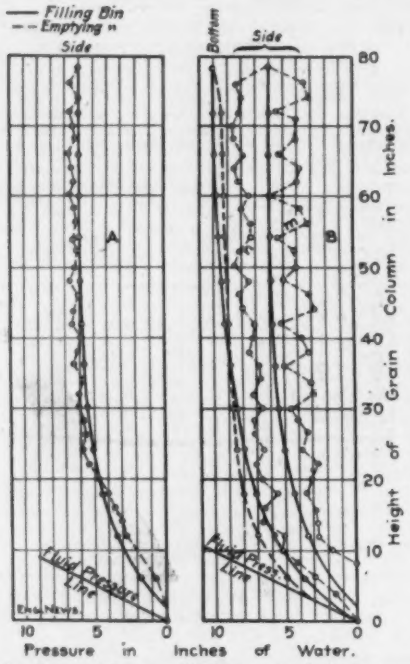


Fig. 8. Curves Showing Variations in Grain Pressure Due to Filling and Emptying Bins, with Outlet Opening at Center or at Side of Bottom; Model-Bin Tests.

A—Curve of side pressures, outlet opening in center of bottom.
B—Curves of side and bottom pressures, outlet opening at side of bottom.
Note.—Side pressure is shown both for side adjacent to outlet (curve m), and for side opposite outlet (curve n).

walls, is very slight and may be neglected, and assume that the full weight of the first layer is resting on top of the second layer. We therefore have:

$$\frac{5{,}000 \times 40}{100} \times 0.6 \times 0.41667 = 500 \text{ lbs.}$$

carried by the walls.

This 500 lbs. deducted from the weight of the second layer will leave 4,500 lbs. (which we will call the remaining weight) plus the full weight of the first layer, making 9,500 lbs. which will rest on top of the third layer, and will produce lateral pressure in the third layer sufficient to support 950 lbs.; deducted from the weight of the third layer this will give a remaining weight of 4,050 lbs. Adding this to the remaining weight of the second layer, and the full weight of the first layer, will give the pressure on top of the fourth layer, and so on for all succeeding layers. As the weight on top of each layer increases, the lateral pressure will be correspondingly increased, and the greater the pressure against the walls, the greater proportion of each layer that will be supported by the walls. While the weight being added to the bottom pressure by each succeeding layer, will correspondingly decrease, until a depth has been reached where the pressure against the sides becomes sufficient to cause the full weight of the layer to be supported, by the walls, then the maximum lateral pressure has been reached, and no further weight will be added to the bottom. The total weight on the bottom of a bin will therefore be equal to the sum of the weight of the top layer plus the remaining weights of all succeeding layers, and the weight carried by friction on the bin walls will be the difference between the weight on the bottom and the weight of the total amount of grain in the prism of the bin.

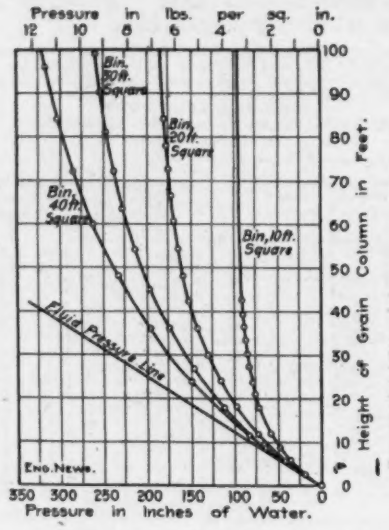


Fig. 9. Computed Curves of Pressure for Wheat in Bins of Various Sizes.

Weight of wheat, 50 lbs. per cu. ft..
Angle of repose, 28°.
Coefficient of Friction bet. grain and bin-side, 0.417.

This may be called the "step process," and calculations may be made in this manner to obtain the pressures in any given size or construction of bin filled with grain or any other strictly granular material.

Table III., on p. 239, gives the pressures for bins 10 ft. and 20 ft. square and 80 ft. deep, was calculated by the above process. The two columns at right of the tables give the pressures calculated by "Pressure Factors" obtained by the tests.

While this process is very simple, it is a somewhat long and tedious one, by which to make the calculations for deep bins; but is undoubtedly correct and agrees in every particular with the results obtained from the author's tests, both in the model and full-sized bins, and also with Janssens' tests, mentioned earlier in this paper. This process may, however, be reduced to a very simple formula since we find that no matter how deep the bin may be, if the walls be not compressed vertically due to the load, we can readily find the maximum vertical and lateral pressure in a bin of any given dimensions, filled with any granular material.

Assuming as above, a bin 10 ft. square, filled with wheat weighing 50 lbs. per cu. ft., the coefficient of friction between grain and the bin walls as 0.41667 and the angle of repose of the grain as 28° and therefore the ratio of bottom to side pressure as 1:0.6. We have the total side pressure required in a layer 1 ft. deep to support the total weight of that layer by friction on the wall, as follows:

$$L = \frac{5{,}000}{0.41667} = 12{,}000 \text{ lbs. pressure to support } 5{,}000$$

lbs., and the side pressure per sq. ft.

$$I = \frac{5{,}000}{0.41667 \times 40} = 300 \text{ lbs., or } 2.08 \text{ lbs. per sq. in.}$$

The bottom pressure per sq. ft. will therefore be

$$V = \frac{5{,}000}{0.41667 \times 40 \times 0.6} = 500 \text{ lbs., or } 3.47 \text{ lbs. per}$$

sq. in. and the total bottom pressure will be

$$\frac{5{,}000 \times 100}{0.41667 \times 40 \times 0.6} = 50{,}000 \text{ lbs. on horizontal}$$

bottom.

It happens that this 50,000 lbs. total weight on the horizontal bottom of the bin is exactly equal to the weight of a column of grain having a height equal to the horizontal dimensions of the bin, and this would hold true for any square or cylindrical bin having the same coefficient of friction, filled with material having the same weight and angle of repose. If, however, the coefficient of friction should be lower, the weight on the bottom will be correspondingly higher, or vice versa. If the angle of repose should be lower and the coefficient of friction between the grain and the bin walls remain the same, then the lateral pressure would be greater, and the weight on the bottom lower, but since a lower angle of repose of the grain will usually give a lower coefficient of friction, between the grain and the bin walls, the angle of repose of the grain will always have considerable bearing on the latter, in addition governing the relative vertical and lateral pressure.

We will therefore assume a bin of the same size as before, filled with grain weighing 50 lbs. per cu. ft. with the coefficient of friction as 0.35, angle of repose of grain 24° and therefore a ratio of bottom to side pressure of 1:0.65. We have the side pressure per sq. ft.:

$$I = \frac{5{,}000}{0.35 \times 40} = 357 \text{ lbs., or } 2.48 \text{ lbs. per sq. in.}$$

Bottom pressure per sq. ft.

$$V = \frac{5{,}000}{0.35 \times 40 \times 0.65} = 549 \text{ lbs., or } 3.82 \text{ lbs. per sq. in.}$$

and the total bottom pressure

$$\frac{5{,}000 \times 100}{0.35 \times 40 \times 0.65} = 54{,}946 \text{ lbs. on horizontal bottom.}$$

It must be borne in mind that the preceding formula gives only the maximum vertical and lateral pressures and grain load on the horizontal bottom of the bins when the bins are being filled, or the grain at rest. No matter how deep the bin may be, if the bin walls be not compressed vertically due to the load these maxima will not be materially exceeded.

In a bin having a hopper bottom, the weight of grain in hopper must be added to the total weight on horizontal bottom.

The pressures obtained by the foregoing system of calculation agree accurately with the tests made in the model bins, and the pressures obtained in the latter, multiplied by the increased breadth or diameter agree most closely with the tests made in the full-sized grain bins of the same ratio of breadth to depth.

The author believes that he has fully demonstrated that the pressure produced by grain stored in deep bins is only a small percentage of the pressure that would be produced by fluids of the same specific gravity, and that the pressures produced by grain or any other dry granular material stored in bins of any dimensions may be accurately calculated.

Wheat and corn are the two varieties of grain which are most largely stored and handled. Taking wheat weighing 50 lbs. per cu. ft., as a standard, we find that corn weigh-

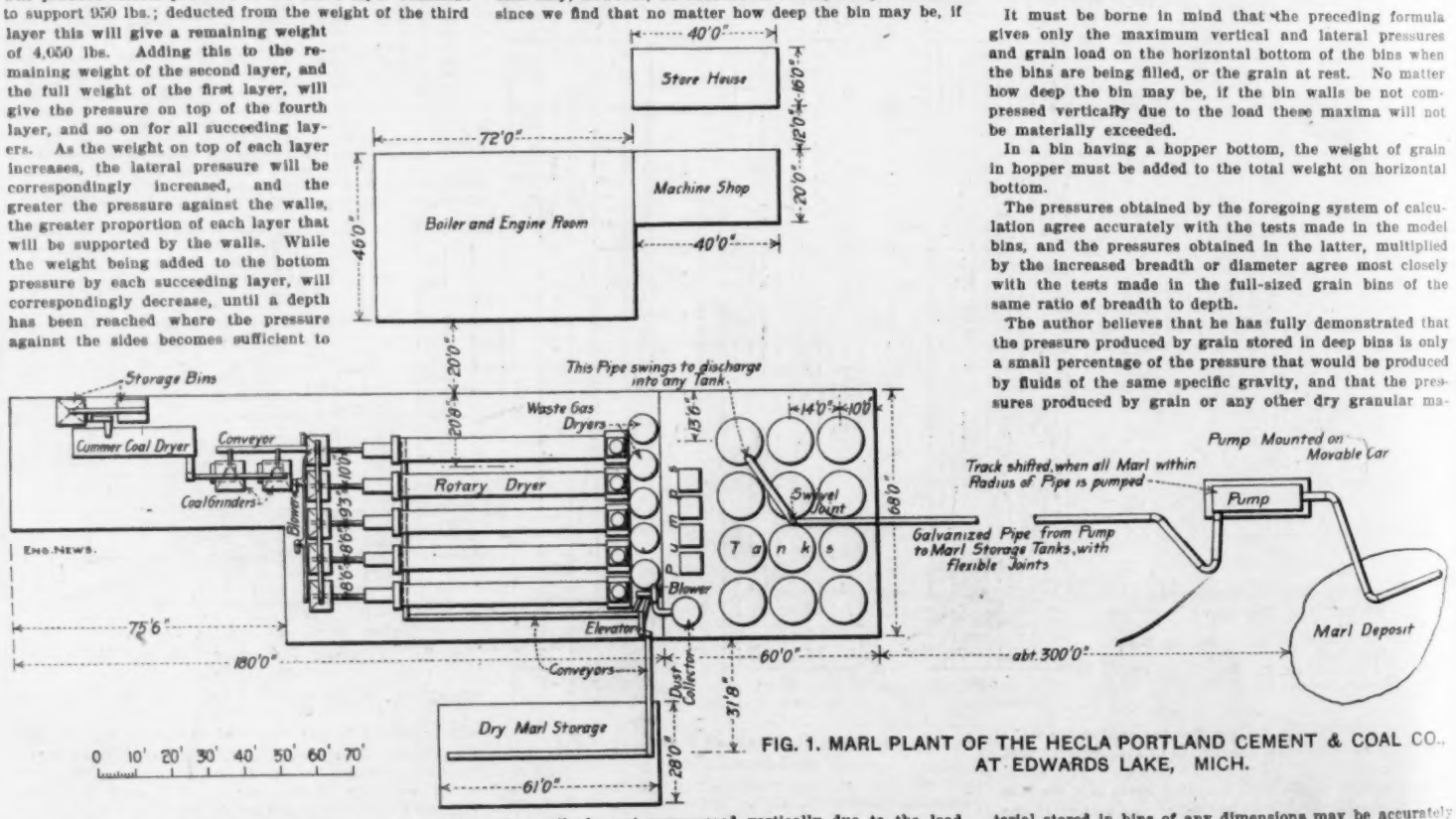


FIG. 1. MARL PLANT OF THE HECLA PORTLAND CEMENT & COAL CO., AT EDWARDS LAKE, MICH.

lbs. per cu. ft., will give approximately the same pressure per square inch as wheat; this being due to the slightly lower coefficient of friction between the corn and bin walls. Peas, weighing 50 lbs. per cu. ft. give a vertical and lateral pressure of approximately 20% greater than wheat; while flax-seed, weighing 45 lbs. per cu. ft. will give a lateral pressure 10% greater, and a vertical pressure 12% greater than wheat, this being due to its lower angle of repose, and lower coefficient of friction. A bin designed with a proper factor of safety for wheat will, however, be quite safe for the storage of peas or flaxseed.

PLANT AND BUILDINGS OF THE HECLA PORTLAND CEMENT & COAL CO.

The Hecla Portland Cement & Coal Co., of Bay City, Mich., has its main plant for the manufacture of Portland cement located at Bay City, on the west bank of the Saginaw River. The raw materials, however, are brought from a distance. The marl is obtained from beds on swamp lands at Edwards Lake, about 50 miles from Bay City, and at the lake is a marl drying plant.

The shale, which is very hard and dry, is obtained from one of the coal mines which are owned and operated by the company, and which supply coal for the dryers, boilers and kilns. These mines are about seven miles from Bay City, being connected with the cement plant by the company's private railway. The cement plant is intended to have a capacity of 8,000 barrels per day, in separate units of 2,000 barrels capacity each. Half of the first unit is completed and in operation, and machinery is being installed for the second half. For particulars of the plant we are indebted to Mr. Ellis C. Soper, formerly Chief Engineer of the company.*

MARL PLANT.

The marl beds at Edwards Lake lie in a large swamp, and the marl is excavated by means of an orange-peel bucket dredge made by Kaltenbach & Griess, of Cleveland, O., the bucket having a capacity of about 1 cu. yd. This machine runs on a track and is self-propelling. It dumps the marl into the sump of a pump which is mounted on a flat car behind the dredge. This pump forces the marl through a 10-in. galvanized steel pipe to 12 storage tanks 12 ft. in diameter, in the first building, shown in the plan, Fig. 1. From these tanks four Bonnot slurry pumps pump the marl to the five waste-gas dryers, there being one of these dryers to each rotary dryer. All the waste gases pass through these dryers before escaping to the air, and in this way their heat is utilized. The material passes through these waste gas dryers, and by screw conveyors is delivered into the hoppers feeding the rotary dryers. These rotary dryers, shown in Fig. 2, are 6 ft. in diameter and 60 ft. long, lined with fire-brick and equipped with special combustion chambers for igniting the coal. The dryers are fed with wet marl from the feed hoppers by means of small screw conveyors. These dryers discharge into a conveyor which in turn discharges into an elevator, and the marl is then conveyed to the dry marl storage building. This structure is 72 × 32 ft., 60 ft. high, and is built entirely of concrete-steel construction. It has a capacity of 1,500 tons. The dry marl is discharged from the storage bins into specially made covered steel cars of 50 tons capacity, in which it is hauled to the Bay City plant over the Michigan Central R. R.

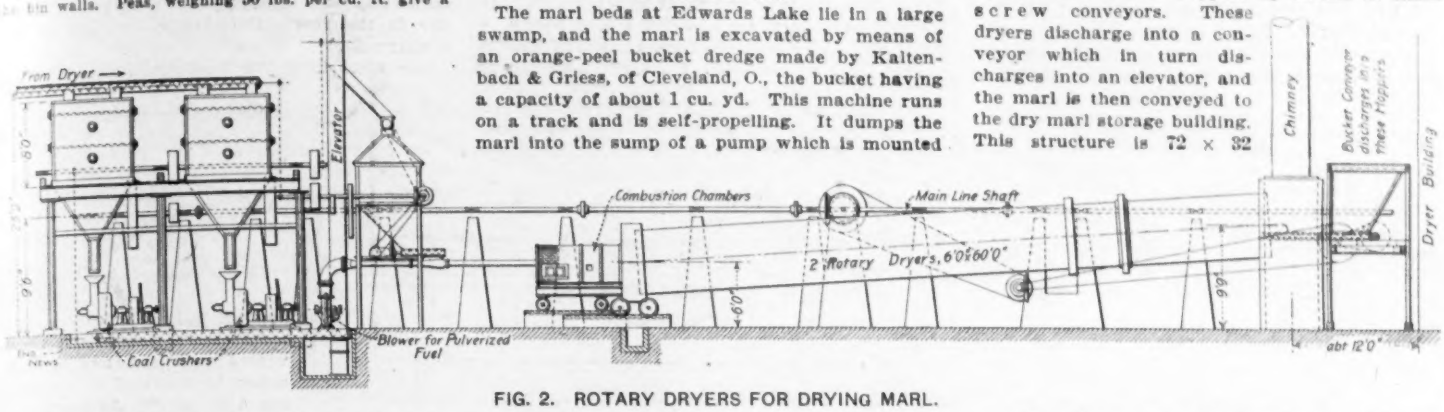


FIG. 2. ROTARY DRYERS FOR DRYING MARL.

*Now with the Engineering Co. of America, 159 La Salle St., Chicago.

The rotary kilns are fired by pulverized coal, the dust-fuel burners being of the Sturtevant Co.'s make. The coal for these kilns is dumped from a trestle into a concrete hopper, whence it passes to a Cummer dryer, and then to two Sturtevant crushers or pulverizers. The pulverized coal is delivered into feed bins, from which it is blown by a blast from two fans into the combustion chambers which adjoin the hoods of the kilns.

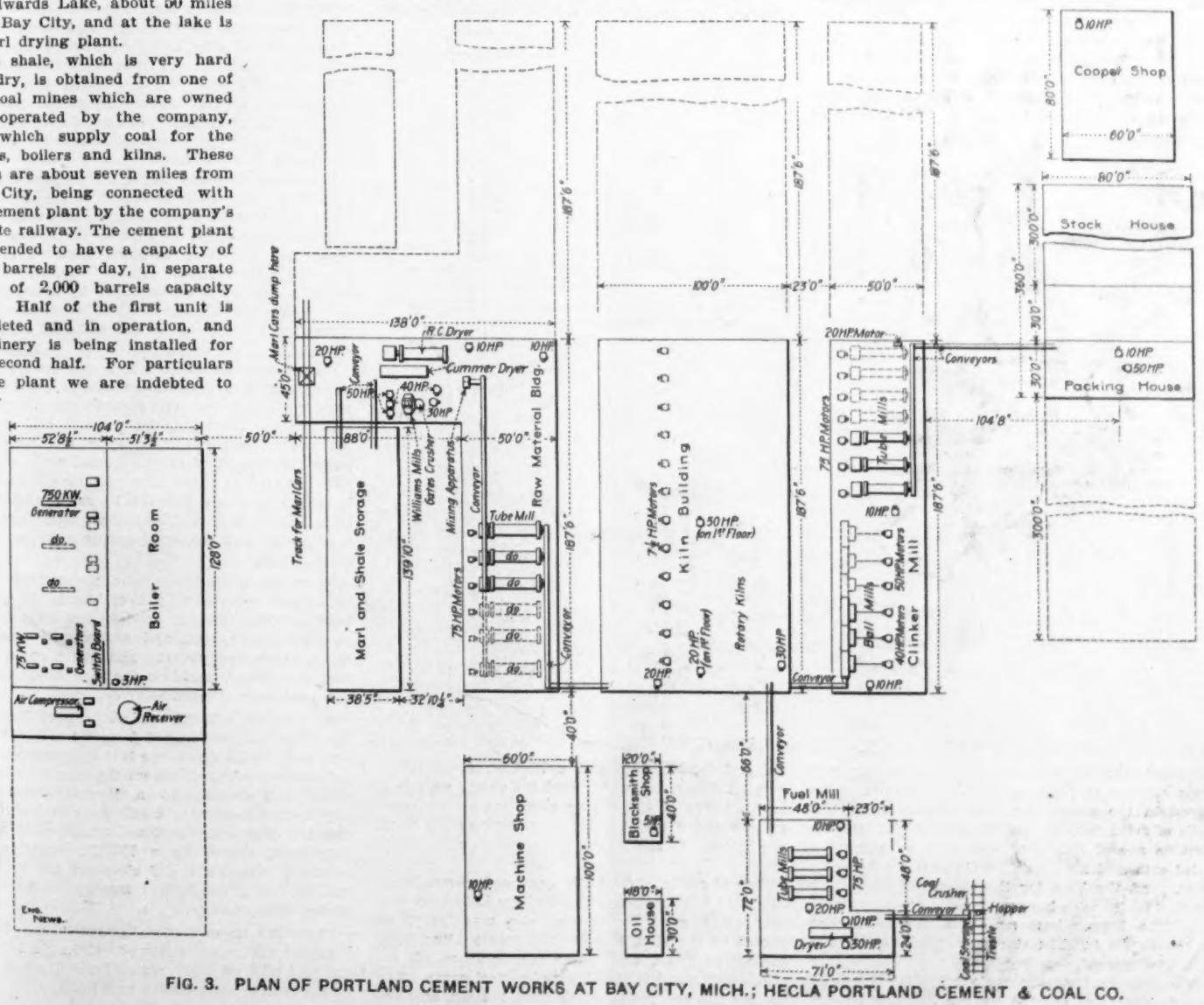


FIG. 3. PLAN OF PORTLAND CEMENT WORKS AT BAY CITY, MICH.; HECLA PORTLAND CEMENT & COAL CO.

This plant also includes a boiler and engine house, and a machine shop. The power plant comprises three Franklin water-tube boilers of 150 HP., and two horizontal compound Ide engines of 125 HP. Power is transmitted by means of the main line shafts and numerous countershafts. There is also a small 22½-KW. generator

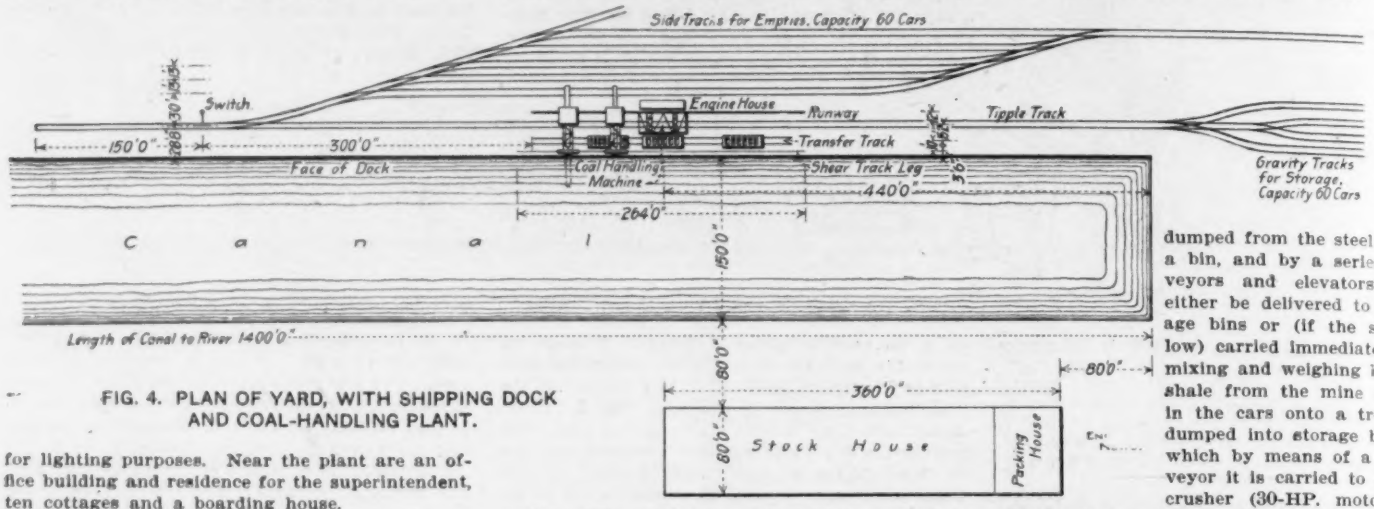


FIG. 4. PLAN OF YARD, WITH SHIPPING DOCK AND COAL-HANDLING PLANT.

for lighting purposes. Near the plant are an office building and residence for the superintendent, ten cottages and a boarding house.

CEMENT PLANT.

The main plant at Bay City, Fig. 3, for the manufacture of the cement, consists of a power house, marl and shale storage houses (carrying two weeks capacity of raw material); raw material building, rotary kiln building, clinker mill, stock and packing house, and a fuel mill. There is also a blacksmith shop, machine shop, cooper shop, oil house and office building.

The buildings are all of steel frame construction, with concrete-steel walls, with the exception of the marl and shale storage, stock house and blacksmith shop. The concrete walls of the main buildings are about 2 ins. thick, reinforced with

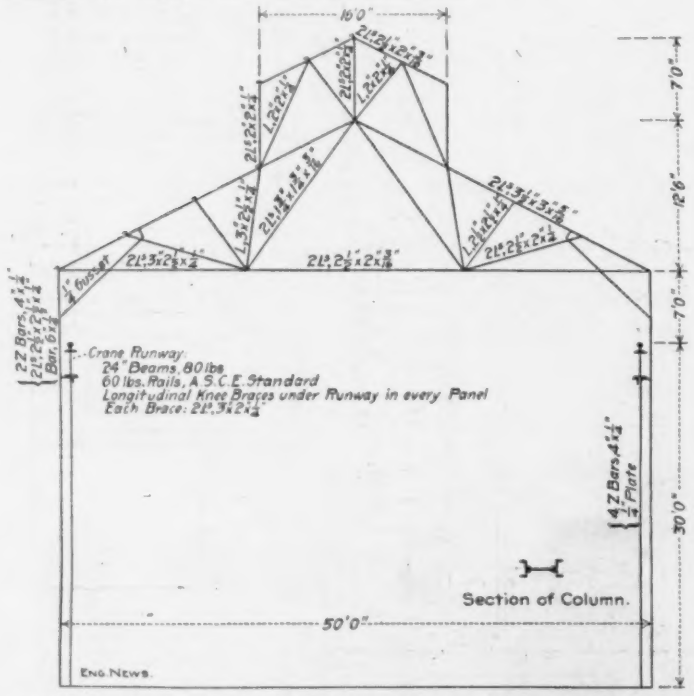


FIG. 5. SECTION OF RAW MATERIAL BUILDING OF CEMENT WORKS.

expanded metal lath in the center. The marl and shale storage is built entirely of concrete, reinforced in the same way. The stock house has walls of solid concrete, carrying steel roof trusses. Its bins are of concrete, reinforced by expanded metal lath and iron rods. This building is 300 × 80 ft., and the bins for the reception of cement are 80 × 20 ft., with hopper bottoms at an angle of 45°. The hopper bottoms are 6 ins. thick, the span being 80 ft. The storage capacity is 120,000 barrels of cement.

The steel work of the main buildings was designed, built and erected by the Indiana Bridge Co., of Muncie, Ind., and the concrete work was put in by the Hecla company.

The power plant consists of a battery of four Franklin water-tube and three Babcock & Wilcox water-tube boilers, each of 300-HP. capacity; a 1,200-HP. Allis-Chalmers cross-compound Corliss engine, and a 1,200-HP. McIntosh & Seymour engine. The engines are directly connected to Westinghouse 750-KW. alternating-current generators and run condensing. The exhaust steam from these engines and from the pumps is used for heating the feed water, this water being afterwards passed through a filter and purifying system.

Three 75-KW. generators (two for reserve) are provided for exciting the field of the main generator and for lighting, and a 75-KW. alternating-current generator is also used for power purposes. In an annex of the engine room are an air compressor and a receiver for furnishing air to clean the motors, to run forges in the blacksmith shop, etc.

The plant is electrically equipped throughout, about 45 Westinghouse three-phase induction motors being used for driving the machinery, as shown on the plan, Fig. 3. The rotary kilns, tube mills, ball mills, and Gates crushers are all directly connected to the motors by steel gears. The motors are encased in small cloth frames, and are

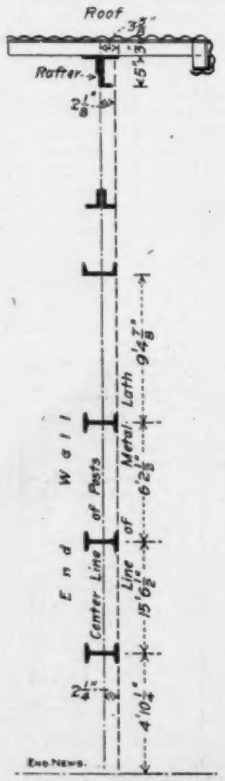


Fig. 6. Section Through End Wall of Building.

protected from dust by a constant current of air from the compressor in the annex of the engine room. There are three electric traveling cranes, each of 15 tons capacity; one in the power house, one in the raw material mill, and one in the clinker mill.

The marl from the Edwards Lake plant is dumped from the steel cars into a bin, and by a series of conveyors and elevators it may either be delivered to the storage bins or (if the storage is low) carried immediately to the mixing and weighing bins. The shale from the mine is carried in the cars onto a trestle, and dumped into storage bins, from which by means of a pan conveyor it is carried to the Gates crusher (30-HP. motor), which discharges into two Williams mills (each driven by a 50-HP. motor). It is then elevated and conveyed to a Ruggles-Coles dryer (10-HP. motor). This dryer discharges into an elevator, and the dry shale is conveyed either to the shale storage bins or to the weighing and mixing bins, should the storage be low. Two 40-HP. motors drive the conveyors and elevators in this building.

The proportions of marl and shale are weighed, discharged into an elevator, and conveyed to three tube-mill bins, and thence fed to three Gates tube mills, 5 × 22 ft. In these the material is more finely ground and mixed. Each tube mill is driven by a 75-HP. motor. From the tube mills the "raw mix" is conveyed and elevated into the six feed bins in the rotary kiln building. This will eventually have 12 kilns.

The present rotary kilns are 78 ins. diameter and 60 ft. long, each driven by a 7½-HP. motor. They are located 20 ft. above the ground on a concrete-steel floor, and have an inclination of ¾-in. per ft. Their calcined contents are discharged into vertical clinker coolers, through which a current of air is blown by a fan, the hot air from the clinker cooler being discharged through the blast pipe of the coal-feed hoppers of the kilns.

The coolers discharge into a pan conveyor, and the clinker is elevated to automatic weighers and then conveyed and elevated to the Krupp ball mill bins. Each of the present ball mills is driven by a 40-HP. motor. From the three Krupp mills the cement of the first grinding is conveyed and elevated to three tube-mill bins, from which it is fed to three Gates tube mills, each driven by a 75-HP. motor. The cement from these mills is elevated and conveyed across a bridge to the stock house.

From the stock-house bins, the cement is conveyed and elevated to packer bins in the packing house, from which it is delivered by automatic packers into barrels and sacks. Alongside the stock house and packing house is a canal to the Saginaw River, enabling the lake boats to enter and load with cement.

At the fuel mill the coal to be used for fuel in the kilns, etc., is dumped from a trestle into storage bins, which discharge into a conveyor leading to a coarse crusher. From the crusher it is conveyed and elevated to a Ruggles-Coles dryer, which discharges into a still finer crusher. From this the coal is elevated and conveyed to a Gates tube mill, driven by a 75-HP. motor, and by means of conveyors and elevators the pulverized coal is finally discharged into the coal-feed bins of the rotary kilns.

There are three dust collectors; one in the raw material mill, on the Ruggles-Coles dryer; one in the fuel mill, on the Ruggles-Coles dryer; and one in the clinker mill, on the ball mills.

Opposite the stock house, and on the canal above mentioned, is a Brown-Hoist rapid coal-handling plant, which the company has installed for the purpose of shipping coal from its mines to the lake ports. This is shown in Fig. 4.

STRUCTURAL WORK OF BUILDINGS.

Mill-building construction is now such an important feature in the structural steel industry that it will be of interest to consider the design of some of the buildings of the Hecla company's plant. As already described, the principal buildings are of steel-frame construction, with concrete-steel walls filled in between the columns. The stock house has heavy concrete walls supporting the roof trusses. The roofs are covered with No. 20 galvanized corrugated steel, except the power house, which has a 2-in. wooden sheathing and slate covering.

The exterior columns in all the buildings are of H-section, built up of either four angles or four Z-bars, with a web plate between. For buildings with second floors, the interior columns are built up of four angles or four Z-bars (with a web plate), and carry I-beam cross girders, between which are framed the I-beam floor girders. The live loads on upper floors are taken as 150 lbs. per sq. ft. (plus weight of kilns, etc.) in the kiln room, and 250 lbs. per sq. ft. in the packing house. The structures are designed to resist a wind pressure of 30 lbs. per sq. ft. The roofs are also calculated for a wind pressure and snow load combined of 30 lbs. per sq. ft. The buildings were designed and built by the Indiana Bridge Co., of Muncie, Ind., and for plans and other information we are indebted to Mr. J. R. Marsh, Chief Engineer of that company.

RAW-MATERIAL BUILDING.—This building is 187½ × 50 ft., with a height of 37 ft. clear to the roof trusses, and 49 ft. 6 ins. to the ridge. Along the entire length is a monitor roof 7 ft. high and 16 ft. wide. The general design is shown in Fig. 5. The columns are composed of four Z-bars up to the crane runway, above which there are two Z-bars and two angles. All the roof members are angles (single or in pairs), while gusset-plate knee-braces connect the trusses with the columns. The crane runways are 24-in. I-beams, carrying 60-lb. rails. In each panel there are longitudinal knee-braces under the runway, each brace composed of a pair of angles. There are nine pairs of columns and nine roof trusses, forming six panels of 2 ft. 9 ins. and two of 22 ft. 6 ins., with diagonal bracing between both upper and lower chords of alternate pairs of trusses. Upon the upper chords are laid the purlins, which are angles 3 × 3 ins. trussed 18 and 24 ins. deep. The end purlins project considerably beyond the gable, as shown by the cross-section of end wall in Fig. 6. At the eaves are struts formed by latticed angles, and also purlins of angles 2½ × 2½ ins. Between the columns are horizontal lines of I-beams, channels and angles, forming the framework, and vertical diagonal bracing is fitted in alternate wall panels.

DRYER BUILDING.—This forms an extension or wing of the raw-material building, and is 88 × 45 ft., with a clear height of 27 ft. Plain triangular roof trusses are used, and there is no monitor roof and no crane runway. Instead of gusset plates between the columns and trusses, angle-iron knee-braces are used.

KILN BUILDING.—This is 100 × 187½ ft., divided into two spans of 46 and 54 ft. The larger span has triangular trusses and monitor roof, while the shorter span has half trusses and a raised skylight. The arrangement and design of trusses is shown in the cross-section, Fig. 7, which also shows the arrangement of the kiln, the fuel and cement feed, and the clinker cooler. The second-floor framing consists of 20-in. I-beams 4 ft. 6 ins. apart, fitted between transverse I-beam girders, and carrying the concrete floor. The tops of the longitudinal beams are 1 in. below the tops of the transverse beams. This framing is supported by columns built up of four angles and a web plate, or four Z-bars and a web plate, according to the loads to be carried.

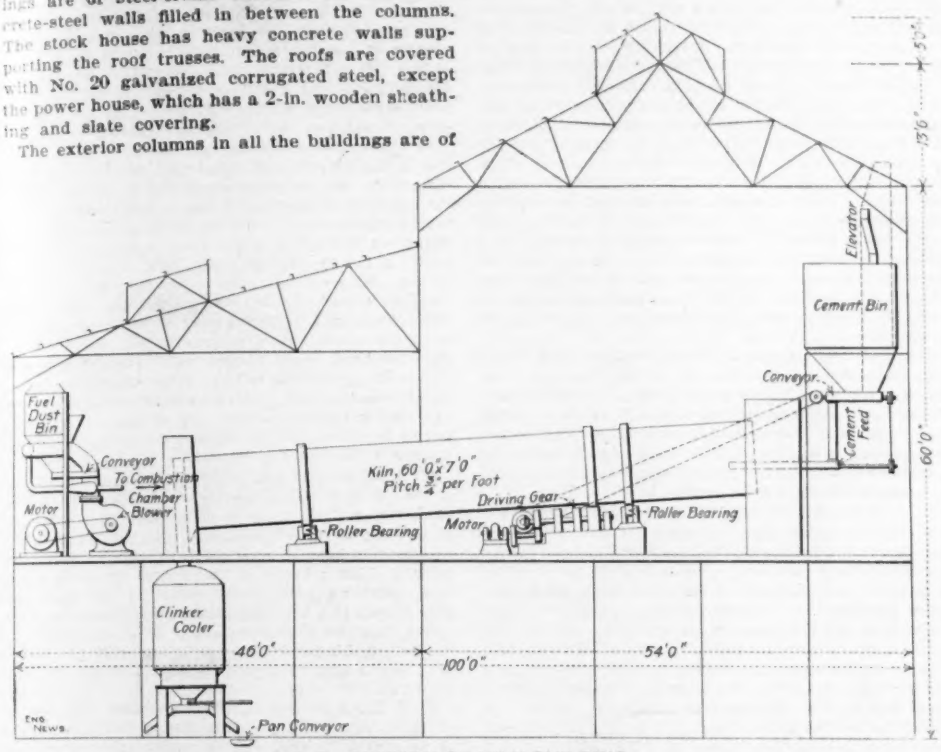


FIG. 7. SECTION OF KILN BUILDING.

CLINKER MILL.—This is of the same design and dimensions as the raw-material building. One of the main columns, carrying the crane runway, is shown in Fig. 8.

STOCK HOUSE.—This is 80 × 330 ft., with concrete walls 14 ft. high, supporting roof trusses 20 ft. apart. This is shown in Fig. 9.

PACKING HOUSE.—Adjacent to the stock house is the packing house, Fig. 10, which is 60 × 80 ft., divided into four bays. The second floor is 60 × 55 ft., and the third floor 60 × 30 ft. The cement conveyor is carried by a bridge 35 ft. long, which extends from the clinker mill to the monitor roof of the packing house, as shown in the cut. This bridge is composed of two parallel-chord trusses 6 ft. 6 ins. deep and 5 ft. apart, with light transverse trusses carrying the roof.

POWER HOUSE.—The power house is 104 × 128 ft., divided longitudinally into an engine room and boiler room. The columns are built up of four Z-bars and a web plate. The roof trusses of the two spans are practically alike, and both have monitor roofs. In the engine room, however, 5-16-in. gusset plates connect the trusses with the columns, in order to have a clear headway for the traveling crane without raising the trusses. In the boiler room, where there is no traveling crane, deep knee-braces are used, consisting of pairs of angles 3 × 2 ins.

NOTES ON THE PHYSICS OF CAST IRON.*

By Richard Moldenke, M. Am. Inst. Min. E.†

I.—CORRESPONDENCE BETWEEN CHEMICAL COMPOSITION, AND MELTING POINT, FLUIDITY, SHRINKAGE, FRACTURE, CHILL, MICRO-STRUCTURE AND OTHER PHYSICAL PROPERTIES.

MELTING POINT.—The melting point of cast-iron had long been a subject of controversy among foundrymen. They knew that a hard iron melted faster than a soft one, but this effect was occasionally disputed, and the reasons given were unsatisfactory, but could not be well controverted. It was my good fortune to take the actual melting temperatures of some 70 pig irons and castings, the Le Chatelier pyrometer suitably protected being introduced into the interior, and the iron melted off in a specially constructed cupola. The irons had been previously analyzed by taking the borings at the point of the introducing the thermo-couple. The results show a regularly ascending scale of melting temperatures as the amount of combined carbon decreased. That is, perfect white iron melted at the lowest temperature, and gray iron containing hardly a sign of carbon in combination resisted the melting heat the longest. This effect means

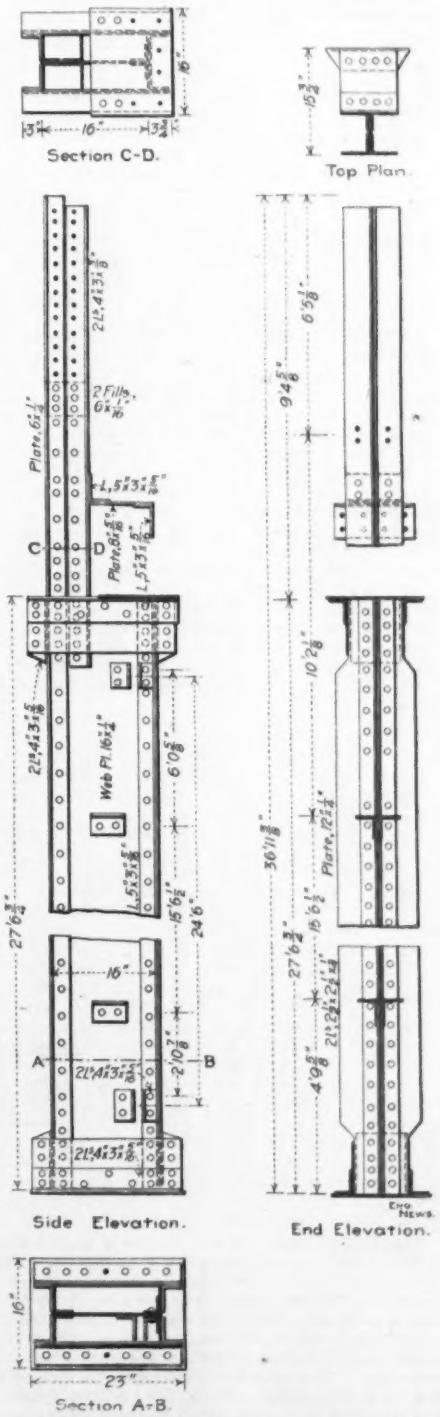


Fig. 8. Main and Interior Columns.

*A paper read at the Atlantic City meeting of the American Institute of Mining Engineers.

†Consulting Metallurgist, P. O. Box 432, New York City.

that a 4% steel, if we may call a white iron thus, which has no graphite in admixture, melted faster than a, say, 0.10-carbon steel with nearly 4% graphite mechanically intermixed, or gray iron. This conclusion seems natural in the light of our knowledge of steel, and, indeed, it seems to have settled the matter effectually.

FLUIDITY.—The fluidity of a cast iron is known to depend in some measure upon the phosphorus-content, yet little has been done in this field, the experience apparently having been accepted without question. It were well if a series of experiments could be made to confirm the assumption, which might throw additional light on the subject of value in other directions. Oxidation has an important bearing on the fluidity of the metal, and a bath of highly oxidized metal loses its fluidity so rapidly by the lowering of the temperature resulting from tapping and carrying, that the ladles "skull" and the molds are short-poured; an effect entirely independent from the phosphorus-content of the metal, be it high or low.

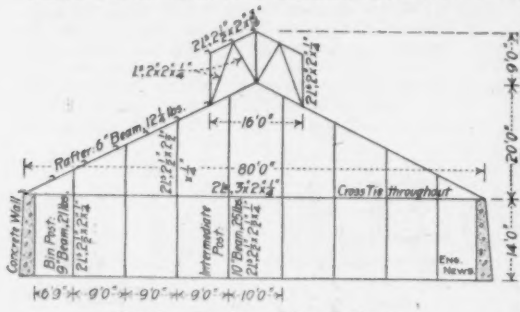


Fig. 9. Section of Stock House.

SHRINKAGE AND CONTRACTION.—On the question of contraction, and its relation to the chemical composition, no general law can be laid down. A dead white iron is supposed to contract a little over 0.25-in. to the foot; a dead gray iron, a little under 0.125-in. to the foot. Between these two typical extremes in cast iron there is a large series of commercial products in which the amount of contraction shades from one to the other. Unfortunately for methods of measuring contraction and judging the composition therefrom, the casting temperature plays sad havoc with the results. A hot iron always has a greater contraction than if the metal were held in the ladle for some time before pouring. Just why this is the case has not been definitely settled. The distinction between contraction and shrinkage should be noted. These terms are invariably confounded by the gray-iron founder. Shrinkage takes place at the moment of set, the metal becoming spongy. Contraction takes place after the moment of set, the red-hot casting slowly contracting as it cools.

FRACTURE.—The fracture of an iron is directly related to its chemical composition; yet it is no criterion of what the iron will be after remelting and casting under normal conditions. The furnaceman who gets more money for the large-grained, black, open-fractured iron than for the close and light gray variety, naturally wants to make only the former, hence all kinds of methods are adopted to achieve this result. Look over the metal yard of a foundry and note the heavy sections that pig iron has come to assume. Also the signs of the sand which has been thrown on the molten metal in order to retard the cooling of the cast. The machine-cast pig iron, which is now beginning to find its way more and more into the foundry, has helped to remove the last vestige of prejudice concerning the fracture question from the otherwise enlightened founder. But long before this machine-cast metal was sold to the founder in large quantities, he had come to realize that the chemical specification alone was the best safeguard. Today the founder who buys by grade and demands a given fracture gets his material, having the desired appearance, but with it, in addition, a nice assortment of composition which would soon bring him to grief were it not for the custom to keep a lot of irons always at hand and in the mixture. The founder who knows, in the meantime, gets the pick of the market.

CHILL.—The hotter the iron is cast, the deeper will be the chill. Unquestionably, the proportion of combined carbon left in a casting is at the bottom of this phenomenon, but why the deeper chill should go with the hotter iron, when exactly the opposite is expected, is a question still unanswered.

II. 1. CUPOLA MIXTURE.—For the cupola mixture, and for that matter the furnace mixture also, the addition of steel-scrap has done much to improve the quality of the castings made in this way. It remains cast iron just the same, but the total carbon has been lowered considerably, which, with a practically constant combined carbon content, means the reduction of the graphite separated out, or, in other words, fewer planes of weakness in the metal. The fracture becomes lighter as a consequence, and the contraction greater. If good results are wanted, about 25% of steel-scrap is the maximum proportion allowable in the cupola. Above this quantity great irregularity in the product is observed. For furnace work, up to 30% can be used; but even here the effect of oxidation becomes quite marked, shrinkage in the interior of the casting too pronounced, residual strains serious, and the molding losses too much to permit. Nevertheless, the moderate use of steel is a good thing in the foundry, and should be encouraged.

When oxidized material is charged, that is to say, burnt iron grate-bars, salamanders and the like, and, to a lesser extent, rusty material, the product will always be bad and were better left alone and put into sash weights. Scrap, very rusty, is not detrimental if some silico-spiegel or ferromanganese is charged with the heat. In the absence of which, however, plenty of limestone, and a little fluor-spar to promote fluidity will be beneficial.

II. 2. MANNER OF MELTING IN THE FOUNDRY.—Although the modern high-pressure production tends to injure the metal, blast pressures are climbing, and coke is sacrified to save time, not so much in order to crowd the pouring to the end of the day for convenience, but because labor exactions have made it necessary to take away from the men as much as possible any excuse for loafing, very little molding being done after the iron begins to run. As our pig irons are not any too good to start with, and the melting processes of the foundry, if anything, injure them still further, a change to conditions which would allow the iron to melt slowly, and be tapped out periodically during the day, would be welcomed. In those cases where the casting is continuous, greater pains can be taken with the charging, fluxing, etc., and possibly in the future the iron may be tapped into a mixing ladle as fast as melted and thence taken to the molds. In this way the iron would not remain in contact with the fuel very long and would have better properties. The European method is to be commended in this respect.

The effect of melting upon the physical structure of the iron is fairly well marked in its subsequent manipulation in the machine shop. Good hot iron in the cupola will not take up as much sulphur as will a cold heat. Hence, a difference in the structure is quickly noticed in planing up a casting. In general foundry work it is good practice to melt very hot, and to hold the iron until cool enough to cast safely. For special work this will not always hold true, as will be shown later.

With a large heat poor slagging-out means dirty iron. At first it does not matter, but after 10 tons or more have been melted, the slag begins to be troublesome. It is better therefore to provide a slag spout and to use it. The result will quickly be noted by a reduced scrap pile in the trimming room. Nothing is paid back so disagreeably as carelessness on the charging platform.

The melting process naturally has an effect on the composition. Manganese and silicon are burned out to some extent, sulphur is unfortunately increased, and the total carbon in the charge will be increased or diminished according to circumstances. There is a tendency to hold a saturation point fixed by the percentage of silicon present. If the total carbon is below this, it will be increased; if above, it may be diminished. In general, the less the silicon, the more the tendency of the metal to take up carbon.

II. 3. CASTING TEMPERATURE.—The casting temperature is a very important item, for the reason that, while one class of work requires very cold iron, another must have it "piping hot." It becomes really a question of surface excellence for the casting to be poured. In one case good chilling effects must be obtained, together with absence of the slightest pin holes, as for instance in the chilled roll, where the metal should be cast as hot as the chills can bear it without fusing. In another case it may be necessary to have some machining done; in this case the metal is poured cold in order not to burn the sand of the mold to the casting. To return to the chilled roll, if this be cast with metal too cold, the casting sets too quickly, and the enormous casting strains produced in the rim from its contraction upon a solidified interior always means trouble. Take the coefficient of expansion of white iron and note just how many inches this makes on a roll 36 ins. in diameter cooled from about 2,000° F. to ordinary temperatures. The inches thus lost in the circumference must be taken up by a suitable stretch in the metal there, and in the case of a cold pour a rupture along the whole face of the casting will result. If, on the other hand, the roll be cast with very hot metal, the rim is at once chilled and set, while the interior is still molten; and by the time the interior sets the solid rim has shrunk to some extent, and at least is sufficiently strong to withstand the internal resistance to final contraction without tearing apart.

II. 5. SIZE AND FORM OF CASTING.—The thickness of the iron in a casting bears a direct relation to the rate of cooling, and consequently on its physical structure, as already explained. Therefore (in making mixtures) it is necessary to keep in mind the thin parts as well as the thick. Thus a heavy dynamo-frame, for which a mixture containing 1.75% silicon would be just right, may have a small thin bracket which requires machining. The silicon therefore must be raised to 2.15% in order to accommodate this part of the proper composition, otherwise the machine shop work may cost more than the additional price paid for the softer iron.

II. 6. KIND OF MOLD, ETC.—The mold itself also has an effect, loam and dry sand methods allowing hotter iron to be used with good surface results in those cases in which green sand would give a badly scabbed or skin-hardened casting. With a very heavy body, the effect is not so marked, for the reason that there is a subsequent annealing proceeding from within outward.

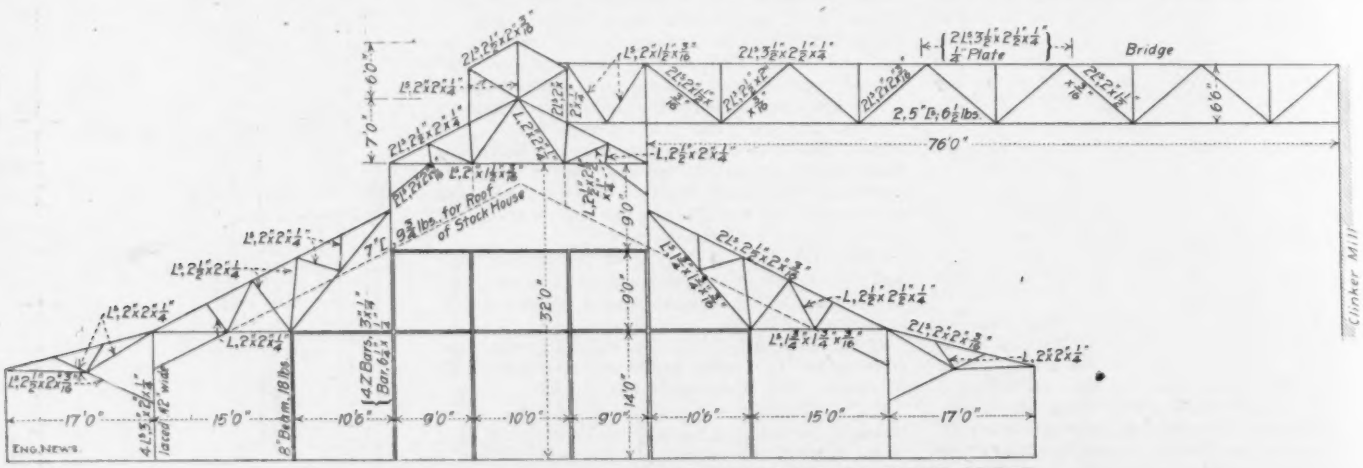


Fig. 10. SECTION OF PACKING HOUSE AND CONVEYOR BRIDGE.

II. 8. MANNER AND TEMPERATURE OF ANNEALING.—The annealing of castings is a study by itself, of which we have still much to learn. The process consists in heating the material to be annealed to a high temperature and then slowly cooling it. Where the sulphur content is fairly low, and the edges of small castings are too hard for rapid machining, annealing them will be beneficial. With higher sulphur it often becomes a question solely of scrapping the lot. Between the annealing process applied to malleable castings on the one hand, and gray iron on the other, undoubtedly the special form of free carbon, known as temper carbon, will be found to play an important part also in the gray iron end of the foundry industry.

II. 9. ADDITIONS OF NICKEL OR ALUMINUM.—The use of aluminum in the foundry is becoming more limited than it was, for the reason that it has been found to be injurious to the harder irons; that is, for hard irons the remarkable property possessed by the light metal of

throwing out the graphite militates against its usefulness. For the soft varieties of iron, a small quantity of aluminum, added when gases are feared, is very good, but, as above mentioned, proper precautions in melting should make the need of this addition unnecessary. On the other hand, the use of titanium iron alloys is to be commended, because the titanium reacts directly with any oxygen or nitrogen present in solution, and, as a consequence, a purification takes place which cannot be overvalued. Increasing the strength of an iron 20% without remaining behind as an integral part of the metal, seems to be the function of this new candidate for foundry favors. With regard to the addition of other metals, such as nickel, cobalt, etc., but little is heard about them in the foundry. These metals, or their alloys, are too expensive, and consequently it is more profitable to use steel castings for material of a strength greater than that of cast iron.

III. SEGREGATION.—The subject of segregation in cast iron is one which could well be studied more fully. Apart from the formation of graphite, which can be considered a sort of distributed segregation, we know very little of the peculiarities of iron phosphide, and still less of iron sulphide, so far as their tendencies to segregate are concerned. On account of the lower melting point of iron phosphide, globules of iron are occasionally found with a higher phosphorus content than the rest of the metal, which have been pushed out of the main body, or have entered into the blow holes in the interior of the casting. By far the most important subject for study is the segregation of the sulphides, and in this field the microscope will eventually prove itself most valuable. Up to the present time this indispensable adjunct to the laboratory has done little for cast iron, partly because the methods of determining constituents other than carbon are practically wanting, and also because our steel experts know very little of cast iron from actual practice.

IV. BLOW HOLES.—With good molding, good iron and good melting, blow holes should not exist, and, generally speaking, they result from errors of manipulation. Where the sand has been rammed too hard, or the venting is imperfect, air is often imprisoned and sent about in bubbles, usually covered over by a skin of iron. If a rather large blow hole exists near the surface, the iron can often be "burned on" and the casting saved. The blow holes to be feared are the small gas-pockets, such as those appearing on the surface of a chilled roll, practically pin head in size, but nevertheless sufficient to condemn the work. In this case the metal is oxidized to an extent that gas is liberated at the moment of set, and becomes imprisoned very near the surface, often causing disastrous results. The trouble with blow holes is usually confined to the low silicon range of cast irons, and were it not for the fact that the addition of aluminum promotes the formation of graphite, this metal would form a valuable corrective. We must look to the future for relief, possibly with ferro-titanium alloys, or the ferro-compounds of such metals as magnesium. If a large furnace heat gives indications of being heavily charged with oxides, the only safe way to act is to add plenty of ferro-silicon, rabble thoroughly, and cast all of the metal into pigs, which can be subsequently fed into the regular mixture in small amounts until the supply of this unwelcome metal is used up.

The future of our studies along the lines indicated above seems to lie in the devising of methods to control the chemical composition of cast iron in cupola and furnace, irrespective of the nature of the pig and scrap charged. Thus we should be able to eliminate sulphur, and perhaps phosphorus, at will. We should also be able to remove the last traces of oxidation, which has been due either to the blast furnace or to the cupola furnace at some previous smelting. With those desiderata the field for the maker of foundry pig iron will be greatly broadened and many an iron ore, now unsalable, would find its way into the market, to the lasting benefit of the world's mineral resources.

NOTES ON GOLD DREDGING IN NEW ZEALAND.

By Gilbert Winslow, B. A., Assoc. M. Inst. C. E.*

The method of dredging for gold in "alluvial wash," at present adopted in New Zealand, is the result of some 30 to 40 years' experiment and improvement. As now carried on, it may be said to be entirely "bucket-dredging," for although suction-pumps have been tried, they have always been discarded.

The essential parts of a working dredge are: the pontoons, which form the barge on which all the machinery is placed in position; the ladder-frame, including the buckets by means of which the wash to be treated is raised; the revolving cylindrical screen and tables, or as an alternative, an ordinary sluice-box, in which the wash is treated; the elevator, not always necessary, for returning the treated wash into the river, behind the dredge, in such a position as not to inconvenience dredging operations; and the winches, for altering the position of the dredge by means of ropes fastened to the shore.

THE PONTOONS.—The pontoons are built of wood or iron. They are always double, with a well about 5 ft. in width between them, extending fully half their length, through which the ladder can be lowered.

THE LADDER-FRAME.—The ladder-frame, built strongly of iron or steel, is so arranged that a chain of buckets can travel continuously round its length. The midship, or upper, end of the ladder-frame, is held at a height of 15 ft. to 25 ft. above the deck of the pontoons, by a strong framing, but the lower end can be lowered through the well to the depth required, by means of blocks and ropes attached to a bridge-like framing, called the "gantry," on the end of the well. The gantry is so built that the ladder can be hauled entirely out of the water. The buckets discharge their contents, when they have passed their highest point, on to a shoot which directs the wash to the revolving screen, if that is employed, or to the sluice-box.

THE REVOLVING SCREEN.—The revolving screen is open at both ends, revolves slowly on its axis, which is out of the horizontal, the end which receives the wash being higher than the other end by 1 ft. to 2 ft., depending on the length of the screen. As the screen revolves, matrial put in at the higher end will in due course be delivered at the lower end. Water plays on the wash in the screen from end to end. The screen is perforated with holes as close together as possible, consistent with strength, and varying in diameter between ¼-in. and 1¼ ins., according to the coarseness of the gold which it is expected to catch. The larger material is delivered from the lower end of the screen into the elevator. All the gold and smaller particles of the wash are washed through the holes, and fall directly on to the tables, which have a width equal to the length of the screen, and a length of about 8 ft. or more, if space allows. The tables are covered with plush or felt, having a protection of "expanded metal" laid over it. The fall of the tables may be 1½ in. in 1 ft., and the water frequently flows over the tables with a depth of ½ in. When once the gold and finer product are on the tables, the separation of the gold is effected by gravitation. The water thoroughly disintegrates the product on the tables, and, at the first opportunity, the particles of high specific gravity, such as gold and heavy black sand, fall through the expanded metal on to the plush, where they are caught. The lighter particles at the same time are carried away by the water. The stream of water must be so adjusted that it is not sufficiently powerful to move gold particles, and yet is too powerful to allow a mass of fine wash to accumulate on the tables, for if this happened the gold could not reach the plush and would be carried away, with the tailings from the tables. The tailings are generally allowed to run into the "paddock" behind the dredge. The tables are "cleaned up" at least once a week, and, if much gold is being caught, as often as once a day.

THE ELEVATOR.—The elevator consists of a frame, somewhat similar to the ladder-frame, the lower end of which is supported on the stern of the pontoons, the upper end being held by means of ropes suitably attached to the pontoons, at the required inclination to the horizontal—generally about 35° to 40°. A continuous chain of buckets travels up the elevator, and as each bucket reaches the top it discharges its contents over the end.

In general, dredging may be divided into two classes, viz., river dredging, and what is commonly called "dry-land" dredging.

In river dredging the elevator is frequently dispensed with, or is thrown out of gear, since the dredge works up-stream, and any stones deposited from the screen over the stern are quickly carried out of the way and do not interfere with the working of the dredge.

In "dry-land" dredging, a dredge frequently has to be built to work into a face of auriferous wash or gravel which stands 10 ft. to 15 ft. above the water-level. In such a case a pond or paddock must be dug, so that the pontoons can be conveniently launched into it. It must be so large that the pontoons can be turned round, with plenty of room to spare. The smallest diameter of the pond should be 40 ft. longer than the dredge, for by having extra room much time is saved in "opening out" when commencing work. There is, of course, a limit to the height of the face into which it is possible to work. An elevator cannot deposit gravel masses as closely as nature has done it. A dredge, well managed and having no other special difficulties to cope with, should take down a face of x ft. in height, from the surface-level to the bottom which it is proposed to clean up, and deposit the same material, less that which has escaped through the screen-holes, in a vertical height of $\frac{3x}{2}$ ft. Thus, if the water-level is 20 ft. above the bottom, and a dry face is exposed for a height of 10 ft. above water level, a total face of 30 ft. in height is to be dredged, and this when stacked behind should not occupy more than 45 ft. vertically. Of this height, 20 ft. will be below water level and 25 ft. above it. Tailings-elevators, as at present used, become very cumbersome and expensive if designed to stack more than 25 ft. above water level. Matters can be assisted somewhat by bringing an artificial supply of water into the paddock and keeping the water above its natural level. Under certain circumstances it would be possible to reduce say, a 20-ft. face above, and a 10-ft. face below water level, to a face all below water level, but this is an extreme case never likely to occur, and such a claim should be proceeded with very cautiously, for, if the natural water level is so low, it is quite possible that at some previous time much of the ground may have been drained and worked by mining. Moreover, should the water suddenly escape from the pond or paddock, the dredge might become stranded. The dredge attacks a face and deposits it behind, thus continuously moving the pond or paddock onward in any direction it is desired to work. It is always advisable to keep the paddock as wide as possible and to work on a definite system, as this is more economical in every way than working haphazard. If no system be adopted at the start, it may be found at some future time to be impossible to work part of the claim without going through old tailings again. In dry-land dredging there is little danger of stoppage due to the dredge being carried away by floods. That, however, is not a very serious item in river dredging, for most dredges can be pulled up by dropping the ladder. Rivers do not lend themselves so readily to prospecting as dry land, and results in river dredging are generally more irregular than those in dry-land dredging, the weekly returns from the rivers being sometimes very large and sometimes very small.

DIFFICULTIES IN DREDGING.—It will easily be conceived that gold washed down a river may lodge in a crevice in a rock bottom, and may be absolutely irrecoverable by means of a bucket; for this reason a hard bottom constitutes a serious defect in a dredging-claim. Moreover, gold in a face loosened by undermining may fall down and be lost, as far as the dredge is concerned, and thus both the gold on the bottom and that in the higher strata may be lost. Perhaps the most important part of a dredgemaster's work is to see that the bottom is cleaned up, and a few inches of it brought to the surface, for gold appears to work its way into a soft bottom. If the bottom is composed of rock no bucket can clear it effectively.

The presence of too much soft clay, or even of any at all, may prove a source of considerable loss. In general, it has been found in New Zealand that in a very clayey ground better results are given by a sluice-box than by a revolving screen in the matter of saving gold. It is not difficult to find a reason for this. In a sluice-box, any gold in the wash not mixed with clay has an opportunity, immediately after the disintegration of the wash under the action of a powerful stream of water, to fall to the bottom, between riffles, where the clay lumps cannot reach it. In a screen, however, the gold cannot be expected to go through the first hole it comes to, and that it does not do so in any ground is amply proved by the distribution of the gold across the width of the tables underneath the screen. Until it does find its way through, it will be in constant danger of being picked up by a lump of clay and carried to the elevator and lost.

If a dredge claim happens to be situated in a river into which trees might find their way, and into which much sluicing has been done, there is a strong probability that there will be a certain amount of buried timber. This, if in large quantities, involves a tremendous loss of dredging-time, and may even make a claim undredgable which without buried timber might be considered ideal dredging ground. Again, a tree carried away by a flood may occasionally get foul of a dredge or its lines. For this and other reasons, if possible, the dredge is frequently drawn into a sheltered position during a flood. A forest on the land to be dredged causes serious inconvenience in many ways. Of course it must be cleared before the dredge can get to work, and as many as possible of the roots should be taken out. These frequently are entangled, and may prevent ground which is undermined from falling in, and generally cause great inconvenience and loss of time. Nevertheless, a forest does not necessarily condemn a claim, for there are claims in New Zealand with thick virgin bush on them, which are now worked with handsome results. Part of the timber can be burned as firewood, but not all of it lends itself to this use.

In certain rivers, such as the Molyneux, in New Zealand, dredging can be carried on with advantage only during about seven months in the year; in summer this river is fed by melted snow, and rises and becomes a torrent until cold weather sets in again. A dredge working in a flooded river may have its buckets coming up full and be apparently treating a huge quantity of stuff. Yet this may be only river silt, containing almost no gold, which is being continuously washed into the paddock. Sometimes the dredge may even be unable to prevent its paddock from becoming filled up with silt. In some localities, also, severe frost may cause a stoppage of several months every year, or the ground may be undredgable altogether on account of the severity of the climate, as in parts of Siberia, where the summer thaw only reaches a depth of 6 ft. from the surface, the ground below that depth being perpetually frozen. Probably a few weeks for an overhaul once a year are necessary on every dredge, and this, if possible, should be done during a forced stoppage, but, if the stoppage is due to frost, it may be impossible to carry out the overhaul.

If in summer the water supply runs short, the gold-saving appliances will be seriously affected and considerable loss may result, for the tables require clean water, particularly if the gold is fine. Care should be taken to prevent the dredge touching the bottom in case of shortage of water, as it might easily be ruined through straining, if it grounded.

*From the "Proceedings" of the Institution of Civil Engineers.

If the gold to be caught cantains large nuggets, and a screen be used, some of the nuggets may be too large to pass through the screen-house, and may become deposited with the tailings. This may be more or less overcome by placing a small sluice-box between the screen and the elevator, so that the material delivered from the screen must pass through the sluice box before being elevated. A more likely occurrence, however, is that the gold is too fine to be saved easily and no system of gold-saving applicable in the limited space available on a dredge has yet been evolved to meet this case. The clumsy device of treating the wash on a separate pontoon has been suggested, but the author has never heard of its being carried into practice. Heavy black sand frequently accompanies gold in alluvial ground. On the west coast of the South Island, New Zealand, certain dredging-claims exist which are sea-deposited and are even only now a few hundred yards from the sea. Here the gold is exceedingly fine, and black sand abounds, so that gold-saving operations are rendered exceedingly difficult. Some progress has been made recently, chiefly by using a large spread of tables, a good flow of water, and a distributing arrangement which makes every part of the table do its work. Large quantities of sand might also present another difficulty, as sand when run into the paddock behind the dredge might run in underneath it. In such a case arrangements might be made to elevate it to some distance away from the dredge.

The regularity or irregularity of deposits can only be ascertained by actual prospecting. The fact that the head of a creek has been drained by a race or by pumps, and has been worked for gold, does not prove that gold exists in the flat below, although, of course, it is an excellent indication. The "lead" of gold worked at the head of the creek may be only a lead running across the present creek bed, deposited by some previous water-course. The creek below may be almost barren until another cross-lead is met with. If the expense of accurately fixing the position of such runs of gold is not prohibitive, it should be done.

Every dredge must be built to suit all the requirements of the claim it is intended to work. Many claims have proved apparently valueless when worked by one dredge, which have afterwards given excellent returns when worked by a more suitable dredge. This has been due mainly to the fact that the first dredge was either not sufficiently powerful or else was unable to dredge deep enough, and had to leave the best part of the wash on the bottom untouched. In designing a dredge for any claim, it is always necessary to ascertain the greatest depth which it may be required to dredge. If the bottom is just so soft that it can be cleaned up easily, it may yet be uneven, or on a regular slope, and so cause difficulty. A ladder of such a length that it will dredge the deeper ground of a claim on being lowered until it approaches a vertical position, has, when in that position, the stresses supported at both ends. If, however, the same ladder be hauled up to dredge much shallower ground, it approaches a horizontal position, and, except for its weight, the principal working-stress will be in the direction of its length, and thus the stress will be sideways instead of downwards on the tumbler-frame which supports the upper end. In such a position the dredge will frequently "kick" as each bucket impinges against the face. To get rid of this trouble, ladders are sometimes made telescopic, so that they may be lengthened or shortened 4 or 5 ft. The deeper ground may be expected to carry more gold than the shallower ground; it should therefore not be missed.

Although a well-designed dredge will probably only need two men per shift, i.e., six men or eight men including the dredge-master and the engineer, yet frequently roads to the ground must be made, and, if timbered, the timber must be cleared, and possibly cut up for firewood; the cost of labor, therefore, must not be dismissed without thought.

It may be possible to do away with expenditure in fuel by the use of electric power generated by water-power. Water power has been used for dredges with good effect. If, however, steam has to be generated, the proximity and cost of coal or wood fuel must be reckoned with. The cost of getting machinery on to the claim must receive as much consideration in dredging as in any other mining proposition.

The wash should not be too coarse, nor should it be excessively hard, due to cement; the proper coarseness is somewhat difficult to specify. Roughly, however, if the boulders do not exceed 18 ins. in diameter, the ground is dredgable. Occasionally boulders of 2 ft. in diameter may be allowed, and although it has been stated that boulders of 10 tons weight have been lifted, they occasion serious inconvenience, and stoppages, if not breakages, will occur. However, it certainly seems that if the wash be coarse the gold has a tendency to be coarse also, and collected in pockets, so that it very frequently pays to move a large boulder, in order to recover what is underneath it.

Prospecting frequently constitutes a most expensive item, and nearly always a most unsatisfactory one. It has been said that the only way to prospect a river is to dredge it. Where that can be done it is undoubtedly a satisfactory test, but it is generally out of the question. Wing-damming is an expensive operation, and very liable to failure. Bore-holes have been put down in a river, but the author does not consider boring-tests satisfactory. When it is considered that a bore-hole of 30 ft. in length and 5 ins. in diameter contains rather less than ⅛-cu. yd., and that gold nuggets up to ½-oz. in weight may easily be encountered, it is easy to see how misleading a boring-test may prove, and no one could expect to get any kind of accurate result. Should the gold be fine and the rods well managed, somewhat more reliable results may be obtained, but even then they cannot be expected to be more than a guide. To prove that gold exists in a claim, boring machines are quite sufficient. A good experienced borer with a good machine may obtain valuable information about a dry-land claim, and as he probably takes his own men with him wherever he goes, the danger from "salting" is minimized. If, however, some idea of the contents of the ground is required, then a shaft sufficiently large must be sunk, and drained either by pumps or by a drainage race. The pump method is not always satisfactory, for with water streaming into a shaft it is quite possible that loose gold may be washed out of the walls, unduly enhancing the result.

Dredging procedure has been likened to a ready-developed mine in which the battery goes about and lifts the auriferous material de situ, but it suffers from one serious drawback from which battery practice is free. In a battery, a check on the battery manager is always possible through the medium of the assayer. It is not so in dredging, however, for it is absolutely impossible to sample the wash as it is lifted, and so the owners are absolutely dependent on the honesty of the dredgemaster. That being the case, the dredgemaster should for his own protection insist on one of the crew being in his presence all the time he is cleaning up, and before leaving the cabin the gold should be put in a bag, weighed, and sealed. So, too, a dredgemaster is very much dependent on the honesty of his crew. It is so very easy during a night-shift to place a handkerchief, spread out, on the table, and when lifted it leaves no mark.

The remarkable progress made in dredging in New Zealand during the last five years has been due in a measure to the excitement caused by the deserved success attending the efforts of a certain party of gentlemen in dredging the Molyneaux River. This river has now been found, with the exception of a few miles, to be dredgable for nearly its whole length, or about 100 miles, and as the river flows for about half its length through very rocky gorges, such a result is remarkable. The river flows from Lake Wakatipu, and, to give two instances of its character, its source is a fine waterfall, and about 35 miles below this is a natural bridge of rocks. So rocky is the Molineaux in parts that one dredge built for convenience on an adjoining claim, was unable to dredge on to the right claim. A large number of claims, which were at their initiation termed "wild cats," are now proved successes. Judging by this, a prospector should not term a gorge undredgable at first sight, for it is not unlikely that it may have a bottom composed of some kind of clayey material, which may prove very rich in gold. From the fact of a river having eaten its way through a rocky gorge, one concludes that it must have been flowing there for many years, and if it reaches the gorge after flowing through an alluvial flat, it is not unlikely that each mile of river-bed may be nearly equally rich in the total quantity of gold it contains, and that a mile of gorge may contain as much as a mile of flat; and if so, the wash in the gorge is concentrated so as to contain, bulk for bulk, much more gold than the flat. Dredging has been accomplished to a depth of 60 ft. below water level, and elevating to a height of 60 ft. above it. These are extremes, and as the machines to do this work are very costly it is advisable to secure claims somewhat easier to work. At the same time a new type of elevator, working by means of centrifugal force, is now being tried, which, if successful, will greatly reduce the cost of elevators. In general, a depth of 35 ft. and an elevation of 30 ft. are quite convenient for a dredge to work.

Claims in New Zealand, which when prospected gave results of 6 grs., over 6 grs., and 1 dwt. to the cubic yard, respectively, have proved failures on dredging; in these cases the prospecting was probably tampered with. The author, without going into details, believes that 3 grs. per cubic yard will give, under good conditions, good results on 100 acres in New Zealand. There, a claim is normally 100 acres, but generally not more than 70 acres of it is dredgable, which may mean a life of about 8 years only, and during that time the first cost of the dredge must be paid, as well as a fair rate of interest on the capital expended.

The author regards dredging as the most speculative of all mining industries, and, except under special circumstances, more suitable for private individuals than for large companies, and he ventures to assert that from its nature it will never be reduced to the science attained by battery and cyanide work.

RATE OF EVAPORATION AT YUMA, ARIZONA.

We are indebted to Mr. J. B. Lippincott, Supervising Engineer of the U. S. Geological Survey, Hydrographic Branch, for a year's record of evaporation at Yuma, Ariz. This is said to be the first complete and accurate record, covering an entire year in this section, which is famous for its high heat and arid climate. It is probably safe to say that the figures may be taken as the maximum rate of evaporation in the United States.

The evaporation pan was placed in one of the small settling domestic reservoirs of the Southern Pacific R. R. near the depot. These reservoirs are surrounded by a picket fence, making an inclosure about 50 × 200 ft. When emptied the water in the reservoir stands about 6 ft. below the surface. For about 18 hours out of every 24, the reservoir is full. Being on a hill, whatever wind is astir is felt here.

This record was kept by Mr. W. D. Smith, Observer for the United States Geological Survey stationed at Yuma, Arizona, the work being in connection with the general investigations of the Colorado River by the Reclamation Service. The figures are as follows:

1903.	Evaporation, inches.	Rainfall, inches.
January	3.32	.00
February	3.48	.23
March	5.28	.00
April	7.21	.00
May	9.84	.00
June	10.25	.00
July	10.75	.04
August	10.70	.00
September	9.05	.67
October	5.79	.04
November	3.80	.00
December	3.39	.00
	82.86	.98
	.98	
Net evaporation	81.88	

DIRECT-METAL AND CUPOLA-METAL IRON CASTINGS.*

By Thomas D. West,† M. Am. Inst. Min. E.

A short time ago, I had occasion to cast plates 1 in. in thickness, with direct metal containing Si, 0.51; S, 0.045; Mn, 0.75; and P, 0.094%. Much to my astonishment I found that there was no trouble in planing them, whereas if cupola metal of like composition had been used, the planing would have been a difficult operation. In view of the interest taken at the present time in the subject of using direct metal for foundry purposes, a few remarks on my observations, while handling this metal in daily routine, may not be amiss, and may create discussion.

I have often noticed a greater fluidity or life in furnace metal when compared with the cupola product. Iron can be seen flowing down the furnace-runners from 50 to 100 ft. before reaching the last pig in very satisfactory shape, while cupola metal might solidify before it had reached one-half the distance. I have seen Bessemer iron in a 30-ton ladle held for nearly an hour and a half during repairs to a crane; and after skimming off the coke dust, it had to be cooled off considerably before being cast.

As a general proposition it is known that the comparatively lower sulphur-content and the higher temperature of direct metal over the same iron remelted in the cupola has much to do with its greater life, yet there are some problems connected with this phenomenon which would seem to call for further study. For instance, furnace metal containing more than 1% silicon holds carbon, which is separated as "kish." This separation does not take place to any great degree while the metal is very hot, but during its gradual cooling, at times, the kish is given off in such large quantities as to cover the ground for an area of from 20 to 30 ft. around the ladle.

Perhaps this throwing out of the excess carbon then makes the life of the metal shorter thereafter. It would be well to ascertain the carbon-content of a ladle of iron during the stages of the cooling process, and thus determine the effect of the carbon reduction more accurately.

In making "direct metal" castings the separation of kish becomes a nuisance, although it is more generally confined to the higher silicon metals. The higher carbon undoubtedly has much to do with keeping metal with the lower quantities of silicon softer, than if it were a cupola product of like composition excepting the total carbon-content. Perhaps some of our furnace friends can throw light on this interesting matter.

RUSSIAN RAILWAYS IN 1901 showed a loss of $7,210,000. During the period of 1897-1900 the annual profits were between $5,665,000 and $9,785,000. The revenues, which amounted to $307,455,000, exceeded the expenditures by $77,765,000. The deficit must be attributed to bad crops and to the construction of 3,000 miles of new lines. The greatest deficit was that of the Siberian Railroad, which amounted to $11,330,000. The above figures are sent to the State Department by Mr. R. T Greener, United States Commercial Agent at Vladivostock.

*A paper read at the Atlantic City meeting of the American Institute of Mining Engineers.

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